MINOR SANITARY ENGINEERING

MINOR
SANITARY ENGINEERING

COMPRISING NOTES ON MATERIALS, PROCESSES, PRINCIPLES AND PRACTICE, INCLUDING 222 PLATES,

BY

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MADRAS
PRINTED AT THE LAW PRINTING HOUSE, MOUNT ROAD.
1916

To

WILLIAM HUTTON, Esq., Assoc. Mem. Inst., C.E.,

SUPERINTENDING ENGINEER, P. W. D., AND SANITARY ENGINEER TO THE GOVERNMENT OF MADRAS,

IN TOKEN OF

THE AUTHOR'S HIGH PERSONAL ESTEEM FOR HIM,

AND IN RECOGNITION OF HIS

PROFOUND KNOWLEDGE IN SANITARY ENGINEERING,

THIS BOOK IS RESPECTFULLY DEDICATED

(WITH PERMISSION)

BY

HIS ASSISTANT,

THE AUTHOR.

PREFACE TO NEW EDITION.

IN this edition, all the Type Designs of the Madras Sanitary Board which were in force on the 1st June 1916 are included in the illustrations.

In each plate are given the numbers of the design and of the proceedings of the Madras Sanitary Board with dates.

The matter of the letter-press has been revised and supplemented to accord with the latest syllabus in Minor Sanitary Engineering as issued by the Government of Madras in June 1914. The specification reports and abstracts of the schedules of quantities of all the designs now included in the volume of plates are given in the letter-press.

I trust that the volumes in their present improved form will be found to satisfy all the requirements, in this branch of their work, of Sanitary Inspectors, Medical Officers of Health, Municipal Authorities and Local Boards.

PILATHOPE,
MYLAPORE, MADRAS, S
10th July 1916.

P. S. KRISHNASAMI.

PREFACE TO FIRST EDITION.

CONSIDERING the grave importance attached to the training in the subject of Minor Sanitary Engineering of Sanitary Inspectors and Medical Sanitary Assistants in this Presidency it is remarkable that no book dealing with this subject and satisfying the requirements of the syllabuses prescribed by the Government of Madras has been issued. This defect was forcibly impressed upon me when preparing my lectures for the classes in Minor Sanitary Engineering. Convinced of the necessity for a suitable text-book that should deal with all the various matters which fall within the compass of the approved syllabuses, I have prepared the present Volumes in which I have endeavoured to bring together, in a concise and practical manner, such information as I believe is most needed by those to whom these Volumes are primarily intended.

In this era of intense interest in all matters relating to public health and practical sanitation, no defence is needed for the presentation of a new book on the subject. This book contains no new theories and no references to methods which have not proved satisfactory in actual use. As an offset to this lack of originality there will be found in the following pages and illustrations considerable information on type designs issued by the Madras Sanitary Board never before collected in an easily accessible form. The editing of this material has been done with the idea of making the result of service to Sanitary Inspectors, Medical Officers of Health, Municipal Authorities and Local Boards.

If the book fulfils its mission of being a suitable text-book in Minor Sanitary Engineering in accordance with the approved syllabuses I shall feel that my effort has not been in vain. If it assists Medical Officers of Health and Local bodies, even to a small extent, in the execution of their duties, it would fulfil its sanitary mission. Whatever it does, the book is out of my hands and will fare as it deserves.

PILATHOPE,
MYLAPORE, MADRAS, S.
31st January 1913.

P. Ś. KRISHNASAMI.

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MINOR SANITARY ENGINEERING.

INTRODUCTION.

Sanitary Engineering.

Doctor Parkes has said "that nothing is so costly in all ways as disease and nothing is so remunerative as the outlay that augments health." The aim of Sanitary Engineering is to root out the former and promote the latter. Sanitary Engineering may therefore be defined as a science and an art by which all conditions hostile to health are removed, and all conditions essential for the health of individuals are secured. This science is progressing so rapidly that if the rapidity of its progress is compared with that of other progressive sciences, it will be found to take the first rank in the list of all sciences that have progressed in their scope of utility and importance during the past half a century. It is not intended to go deeply into the past history of Sanitary Engineering nor into the different stages through which it has developed itself to its present position of importance in the public estimation. I propose to treat this subject from its present condition, as you require for purposes of acquiring a sufficient knowledge of what you need to know as prescribed in the syllabus for Minor Sanitary Engineering. I purposely refrain from any discourse of the past conditions of Sanitary Engineering for the reason, that the schemes of to-day are widely different and more advanced than they were two or three decades ago. The increasing cry "of economy" on the part of the ratepayers demands that Engineers and others who have to deal with Sanitary works, should be thoroughly grounded in the skill and capacity for practical application of Sanitary Engineering in order that all proposals for sanitary works should not only comply with the essential sanitary conditions but should also be of a reasonable cost. A Sanitary Engineer is not merely the product of a mastery of the contents of books on Sanitary Engineering; the difficulties to be contended with in actual practice cannot possibly be solved by a mere persevering study of books on Sanitary Engineering. No two schemes are alike. Obstacles, more or less large, occur in each which probably have not been met with in the schemes which have previously been drawn up and executed. The solution of the difficulties in a feasible, scientific, and economical manner, is a province in which the opportunities of a Sanitary Engineer to show himself to advantage are many and wide.

Obligatory And Discretionary Duties Of Municipalities And Local Boards.

As your employers are the Municipal Councils and Local Boards and as these bodies are administered under certain statutes it would be well if you know what the different Acts that are in force in the different Presidencies and Provinces in India are and what the obligatory and discretionary duties of these Local Bodies as enjoined in the several Acts are. The Acts which are in force on the first of April 1916 in India are as follow:—Bombay:—(1) Act XV of 1876 called the Bombay Municipal Debentures Act, 1876. This Act was repealed in part by Act I of 1879. (2) Act I of 1884 called the Bombay Local Boards Act, 1884. This Act was repealed in part by Act XVI of 1895, by Act III of 1886, Act IV of 1885 and Act I of 1888. (3) Act III of 1888 called the City of Bombay Municipal Act, 1888. This Act was repealed in part by Act II of 1901, Act I of 1897, Act XVI of 1895, Act IV of 1888, Act I of 1894, Act II of 1899, Act II of 1900, Act I of 1910 and supplemented by Act XII of 1888, Act V of 1890, Act I of 1898, Act V of 1903, Act V of 1905, Act III of 1907. (4) Act I of 1889 called the Bombay Village Sanitation Act, 1889. (5) Act I of 1898, called the City of Bombay Municipal Investments Act, 1898. (6) Act IV of 1898 called the City of Bombay Improvement Act, 1898. This Act was repealed in part by Act IV of 1901, Act XIV of 1904, Act III of 1907, Act II of 1908 and Act I of 1913. (7) Act III of 1901 called the Bombay District Municipal Act, 1901. This Act was supplemented by Acts V of 1890 and II of 1899, amended by Act III of 1902, Act I of 1910 and repealed in part by Acts III of 1903, IV of 1904, and X of 1912. (8) Act XIV of 1904 called the City of Bombay Improvement (Supplementing) Act, 1904. Bengal:—(1) Act III of 1884 called the Bengal Municipal Act, 1884. This Act was repealed in part

by Act II of 1888, Act I of 1893, Act IV of 1894, Act II of 1896, Act III of 1899, Act II of 1901, Act I of 1903 and amended by Acts III of 1886, V of 1897 and II of 1910. (2) Act III of 1885 called the Bengal Local Self-Government Act, 1885. This Act was amended by Act I of 1903 and Act V of 1908. (3) Act VIII of 1895 called the Bengal Sanitary Drainage Act, 1895. This Act was repealed in part by Act I of 1903. (4) Act III of 1899, called the Calcutta Municipal Act, 1899. This Act was repealed in part by Act I of 1893 and Act I of 1903. (5) Act I of 1900 called The Darjeeling Municipal Act, 1900. This Act was repealed in part by Act I of 1903. (6) Act II of 1910 called The Bengal Municipal (Amendment and Validation) Act, 1910. (7) Act V of 1911 called the Calcutta Improvement Act, 1911. Madras:—(1) Act IV of 1884 called the Madras District Municipalities Act, 1884. This Act was repealed in part by Act IX of 1888, Act II of 1901, Act III of 1897, and Act II of 1907, and amended by Acts I of 1899, V of 1909, III of 1913 and VIII of 1914. (2) Act V of 1884 called the Madras Local Boards Act, 1884. This Act was repealed in part by Act II of 1901, Act XI of 1901 and Act VI of 1900 and amended by Acts III of 1890, XI of 1901, III of 1913 and VIII of 1914. (3) Act III of 1904 called the Madras City Municipal Act, 1904. This Act was amended in part by Madras Act IV of 1907 and Act II of 1911. (4) Act II of 1907 called the Madras Hill Municipalities Act, 1907. Punjab:—Act XX of 1883 called the Punjab District Boards Act, 1883. This Act was amended by Act XII of 1891, Act I of 1905 and Act II of 1907. (2) Act III of 1911 called the Punjab Municipal Act. Central Provinces:—(1) Act I of 1883 called the Central Provinces Local Self-Government Act of 1883. This Act was amended by Acts XVI of 1899 and XI of 1902 and repealed in part by Act IV of 1914. (2) Act XI of 1902 called the Central Provinces Village Sanitation Act, 1902. (3) Act XVI of 1903 called the Central Provinces Municipal Act, 1903. United Provinces of Agra and Oudh:—(1) Act III of 1906 called the United Provinces District Boards Act, 1906. (2) Act I of 1900 called the North-Western Provinces and Oudh Municipalities Act, 1900. This Act was repealed in part by Act V of 1901, Act I of 1904 and Act I of 1907. (3) Act III of 1894 called the North-Western Provinces and Oudh Sewerage and Drainage Act, 1894. (4) Act II of 1914 called the United Provinces Town Areas Act, 1914. (5) Act II of 1892 called the North-Western Provinces and Oudh Village Sanitation Act, 1892. This Act was amended by Act III of 1906 and Act V of 1912. (6) Act I of 1891 called the North-Western Provinces and Oudh Water Works Act, 1891. This Act was amended by Act II of 1895, Act I of 1908, Act I of 1910 and repealed in part by Act I of 1901. The duties of the Bombay Municipality are as follow:—It shall be incumbent on the Corporation to make adequate provision, by any means or measures which it is lawfully competent to them to use or to take, for each of the following matters, namely:— (*a*) the construction, maintenance and cleansing of drains and drainage works, and of public latrines, urinals and similar conveniences; (*b*) the construction and maintenance of works and means for providing a supply of water for public and private purposes; (*c*) scavenging and the removal and disposal of excrementitious and other filthy matter, and of all ashes, refuse and rubbish; (*d*) the reclamation of unhealthy localities, the removal of noxious vegetation and generally the abatement of all nuisances; (*e*) the regulation of places for the disposal of the dead and the provision of new places for the said purpose; (*f*) the registration of births and deaths; (*ff*) public vaccination in accordance with the provisions of the Bombay Vaccination Act, 1877; (*g*) measures for preventing and checking the spread of dangerous diseases; (*gg*) establishing and maintaining public hospitals and dispensaries and carrying out other measures necessary for public medical relief; (*h*) the construction and maintenance of public markets and slaughter-houses and the regulation of all markets and slaughter-houses; (*j*) the regulation of offensive and dangerous trades; (*k*) the entertainment of a fire-brigade and the protection of life and property in the case of fire; (*l*) the securing or removal of dangerous buildings and places; (*m*) the construction, maintenance, alteration and improvement of public streets, bridges, culverts, causeways and the like; (*n*) the lighting, watering and cleansing of public streets; (*o*) the removal of obstructions and projections in or upon streets, bridges and other public places; (*p*) the naming of streets and the numbering of premises; (*q*) maintaining, aiding and suitably accommodating schools for primary education; (subject always to the grant of building grants by Government in accordance with the Government Grant-in-Aid Code for the time being in force); (*r*) the maintenance of a municipal office and of all public monuments and other property vesting in the Corporation. The Corporation may, in their discretion, provide from time to time, either wholly or partly, for all or any of the following matters, namely:—(*a*) public vaccination; (*b*) educational objects other than those set forth above under obligatory functions; (*c*) constructing, maintaining, or aiding libraries, museums and art galleries; (*d*) constructing or maintaining public parks and gardens and botanical and zoological collections; (*e*) planting and maintaining trees on roadsides and elsewhere; (*f*) surveys of buildings or lands; (*g*) registration of marriages; (*h*) taking of a census; (*i*) preparation and presentation of addresses to persons of distinction; (*j*) providing music for

the people; (*k*) any measures not hereinbefore specially named, likely to promote public safety, health, convenience or instruction. And, with the previous sanction of Government, the Corporation may make such contribution as they think fit towards any public ceremony or entertainment in the city. The duties of the Calcutta Municipality are as follow:—The Corporation shall provide a supply of filtered water within all parts of Calcutta, and a supply of unfiltered water within such parts of Calcutta as they may think fit, and shall cause such separate mains, pipes, and taps to be laid and placed, and such tanks, engines, reservoirs and other works to be made and constructed, either within or without Calcutta, as may be necessary for the supply of filtered water in the principal public streets. The Corporation shall erect sufficient and convenient public stand-posts for the gratuitous supply of filtered water for domestic purposes. All such stand-posts shall be supplied with a sufficient quantity of filtered water, and no unfiltered water shall be supplied thereto. The Corporation shall erect sufficient and convenient platforms for the gratuitous supply of water for bathing purposes. All such bathing platforms shall, as far as may be practicable, be supplied with filtered water; but if it is impracticable to supply any bathing platform with filtered water, unfiltered water shall be supplied therefor. On all distribution pipes in the unfiltered water system, the Chairman shall provide suitable hydrants for street-watering, fire-extinguishing, washing down hackney-carriage stands, and flushing street gullies, together with such sluices, branches and appliances as may be necessary for the efficient flushing of the municipal drains. The Corporation shall gradually convert the existing intermittent system of supplying filtered water into a continuous system. The Corporation shall keep all municipal drains in repair, and shall cause to be made such drains as may be necessary for effectually draining Calcutta. The Corporation shall provide a safe and sufficient outfall, within or without Calcutta, for the proper discharge of the storm water and sewage of Calcutta, in such manner as not to cause any nuisance, whether by flooding any part of Calcutta or of the country surrounding the outfall or in any other way. The plans of the outfall and the method of disposing of sewage shall be subject to the sanction of the Local Government which may, from time to time, direct such alterations to be made as it may consider necessary. If the outfall deteriorates, by the decay of existing river channels or otherwise, the Local Government may require such order to be taken, and such additions or alterations to be made to or in the outfall works, at the charge of Municipal Funds, as it may consider necessary to ensure the proper discharge of storm water and sewage in such manner as not to cause any nuisance as aforesaid. The General Committee shall, out of funds to be allotted by the Corporation, cause the public streets to be maintained and repaired, and for those purposes may do all things necessary for the public safety or convenience, including the construction and maintenance of bridges, causeways and culverts. The Chairman shall provide or appoint, in proper and convenient situations, public receptacles, depots and places for the temporary deposit or final disposal of rubbish, offensive matter, sewage and the carcasses of dead animals; provided that (i) the said things shall not be finally disposed of in any place or manner in which the same have not heretofore been so disposed of, without the sanction of the Corporation, or in any place or manner which the Local Government may disallow; (ii) the powers conferred under this rule shall be exercised in such manner as to create the least practicable nuisance. (2) Any land that may be required in a bustee for the temporary deposit or final disposal of rubbish, offensive matter, sewage or carcasses taken from buildings or land in such bustee shall be provided by the owners of the bustee. For the purpose of securing the efficient scavenging and cleansing of all streets and premises, the chairman shall take measures for securing—(*a*) the daily surface cleansing of all streets and the removal of the sweepings therefrom, and (*b*) the removal of the contents of all receptacles and depots, and the accumulations at all places provided or appointed by him. The Corporation shall maintain an establishment under the control of the Chairman for the removal of sewage from privies and urinals which are not connected with a sewer. The Corporation may, in their discretion, provide from time to time, either wholly or partly, for all or any of the following matters, namely:—(1) the planting and preservation of trees in streets and public places; (2) the construction, alteration, maintenance and adornment of public halls, offices and other buildings under the control of the Corporation or required for Municipal purposes; (3) the laying out and maintenance of squares and gardens; (4) the survey of buildings and lands, and the preparation of plans; (5) the construction and maintenance of hospitals and almshouses; (6) vaccination; (7) the promotion of primary and technical education; (8) the provision of free libraries; (9) with the previous sanction of the Local Government, the payment of contributions to the cost incurred on the occasion of any public ceremony or entertainment held in Calcutta; (10) the payment of contributions to the Commissioners of any neighbouring municipality for expenditure on sanitary purposes; and (11) any other matter which is likely to promote the public health, safety or convenience or the carrying out

of this Act. Under the Madras City Municipal Act, the purposes on which the Municipal Fund may be spent are as follow:—(*a*) Public Safety:—The lighting of public streets, places and buildings; the extinction of fires; the control, supervision or removal of dangerous places, buildings, trades and practices; the regulation of traffic; and the prevention and removal of obstructions in public streets or places. (*b*) Public Health:—(1) The construction, repair and maintenance of hospitals and dispensaries; vaccination; the training of medical practitioners and subordinates; the training and supervision of vaccinators; the registration of births and deaths; the enumeration of the inhabitants of the City; and other measures of a like nature. (2) The construction, maintenance, supervision and control of public markets and slaughter-houses; of latrines, privies and urinals; of drains and drainage-works; of sewage farms; of tramways and other works for the removal of sewage; of water works, drinking fountains, tanks and wells; of parks, squares and gardens; the acquisition of land necessary for any of these purposes; the reclamation of unhealthy localities; and other sanitary measures of a like nature. (3) The cleansing and watering of streets and drains; scavenging; the removal of excessive or noxious vegetation; and generally the abatement of all nuisances. (4) The regulation and control of offensive or dangerous trades, of unhealthy buildings or localities, and of burial and burning grounds; and the provisions of sites for, and the closing of, burial and burning grounds. (*c*) Public Convenience:—(1) The construction, maintenance and alteration of streets, bridges, causeways, culverts and the like; the regulation of buildings; the removal of undue projections; the naming of streets and the numbering of houses; and the planting and preservation of trees in public streets and places. (2) The construction, purchase and maintenance of all buildings under the control of the Corporation or required in order to give effect to the provisions of the Act. (3) The construction, maintenance, alteration and adornment of public halls. (4) The construction and maintenance of alms-houses. (5) The survey of buildings and lands and the preparation of plans. (6) The provision of free libraries. (*d*) Primary and Technical Education:—(1) The construction and repair of school-houses for the poor. (2) Primary education of the poor, including the training of teachers. (3) The promotion of technical education. (*e*) General:—All matters necessary for, or conducive to, public safety, health or convenience. The obligatory and discretional functions of Municipalities in the Presidency of Bombay are as follows:—It shall be the duty of every municipality to make reasonable provision, (1) for the following matters within the municipal district under their authority, namely:—(*a*) lighting public streets, places and buildings; (*b*) watering public streets and places; (*c*) cleansing public streets, places and sewers, and all spaces not being private property, which are open to the enjoyment of the public whether such spaces are vested in the municipality or not, removing noxious vegetation and abating all public nuisances; (*d*) extinguishing fires, and protecting life and property when fires occur; (*e*) regulating or abating offensive or dangerous trades or practices; (*f*) removing obstructions and projections in public streets or places, and in spaces not being private property, whch are open to the enjoyment of the public, whether such spaces are vested in the municipality or belong to His Majesty; (*g*) securing or removing dangerous buildings or places, and reclaiming unhealthy localities; (*h*) acquiring and maintaining, changing and regulating places for the disposal of the dead; (*i*) constructing, altering and maintaining, public streets, culverts, municipal boundary marks, markets, slaughter-houses, latrines, privies, urinals, drains, sewers, drainage-works, sewerage works, baths, washing places, drinking fountains, tanks, wells, dams and the like; (*j*) obtaining a supply or an additional supply of water, proper and sufficient for preventing danger to the health of the inhabitants from the insufficiency or unwholesomeness of the existing supply when such supply or additional supply can be obtained at a reasonable cost; (*k*) naming streets and numbering houses; (*l*) registering births and deaths; (*m*) public vaccination; (*n*) suitable accommodation for any calves, cows or buffaloes required within the municipal district for the supply of animal lymph; (*o*) establishing and maintaining public hospitals and dispensaries, and providing public medical relief; (*p*) establishing and maintaining primary schools; (*q*) printing such annual reports on the municipal administration of the district as the Governor in Council by general or special orders requires the municipality to submit. Municipalities may, at their discretion, provide either wholly or partly, for (*a*) laying out, whether in areas previously built upon or not, new public streets, and acquiring the land for that purpose, including the land requisite for the construction of buildings or curtilages thereof, to abut on such streets; (*b*) constructing, establishing or maintaining public parks, gardens, libraries, museums, lunatic asylums, halls, offices, dharmshalas, rest-houses and other public buildings; (*c*) furthering educational objects other than those setforth under obligatory functions; (*d*) planting and maintaining roadside and other trees; (*e*) taking of a census, and granting rewards for information which may tend to secure the correct registration of vital statistics; (*f*) making a survey; (*g*) securing or assisting to secure suitable places for the carrying on of offensive trades; (*h*) supplying, constructing

and maintaining, in accordance with a general system approved by the Sanitary Board, receptacles, fittings, pipes and other appliances whatsoever, on or for the use of private premises, for receiving and conducting the sewage thereof into sewers under the control of the municipality; (*i*) establishing and maintaining a farm or factory for the disposal of sewage; (*j*) any other measure likely to promote the public safety, health, convenience or education; and (*k*) with the previous concurrence, in the case of City Municipalities, of the Commissioner, or in other cases of the Collector, any public reception, ceremony, entertainment or exhibition within the municipal district. The purposes for which the municipal funds of the District Municipalities of Bengal are applicable are as follow:—The Commissioners at a meeting shall, as far as the municipal fund permits, from time to time cause roads, bridges, tanks, ghats, wells, channels, drains and privies, being the property of the Commissioners, to be maintained and repaired, and the municipality to be cleansed; and may, subject to such rules and restrictions as the Local Government may from time to time prescribe, apply the municipal fund to any of the following purposes within the municipality, that is to say:—(1) the construction, maintenance and improvement of roads, tramways, bridges, squares, gardens, tanks, ghats, wells, channels, drains and privies; (2) the supply of water, and the lighting and watering of roads; (3) the erection and maintenance of offices and other buildings required for municipal purposes; (4) the construction and repair of school houses, either wholly or by means of grants-in-aid; (5) the establishment and maintenance of schools, either wholly or by means of grants-in-aid; (6) the establishment and maintenance of hospitals and dispensaries; (7) the promotion of vaccination; (8) the acquiring and keeping of open spaces for the promotion of physical exercise and education; (9) the training and employment of female medical practitioners and of veterinary practitioners; (10) the establishment and maintenance of veterinary dispensaries for the reception and treatment of horses, cattle and other animals; (11) the appointment and payment of qualified persons to prevent and treat diseases of horses, cattle and other animals; (12) the improvement of the breed of horses, cattle and asses, and the breeding of mules; (13) the establishment and maintenance of free libraries; (14) the maintenance of a fire-brigade; (15) other works of public utility calculated to promote the health, comfort or convenience of the inhabitants. The purposes for which the municipal funds of the District Municipalities of Madras are applicable are as follow:—The District Municipal Funds shall, subject to such rules and restrictions as the Governor in Council may from time to time prescribe, be applicable within the Municipalities in which they are raised, or, with the special sanction in each case of the Governor in Council, without the said Municipalities, to the following purposes; that is to say:—(1) the construction, repair, and maintenance of streets, bridges, and other means of communication; (2) the construction, maintenance and repair of hospitals, dispensaries, lunatic asylums, poor houses, markets, drains, sewers, latrines, water-works, tanks, wells, recreation grounds, gardens, parks and other works of public utility, the payment of all charges connected with the objects for which such works have been constructed, the training and employment of medical practitioners and vaccinators, the sanitary inspection of towns and villages, the registration of births and deaths, the watering and lighting of the streets, the cleansing of the streets, tanks, wells, drains, sewers, latrines and other works of a similar nature and the taking of a census; (3) the planting and preservation of trees; (4) the diffusion of education, and, with this view, the construction and repair of school-houses, the establishment and maintenance of schools, public libraries, reading-rooms, gymnasia or any other institutions connected with the diffusion of education, either wholly or by means of grants-in-aid, the inspection of schools, and the training of teachers; (5) other measures of public utility calculated to promote the safety, health, comfort, or convenience of the people; (6) the payment of any amounts falling due on any loans legally contracted by the Municipal Council; (7) the payment of salaries, leave allowances, pensions, gratuities and compassionate allowances to servants employed by the Municipal Council. The purposes for which the Municipal Funds of the District Municipalities of North-Western Provinces and Oudh, Central Provinces and Punjab are applicable are as follow:—Subject to such rules as the Local Government may make with respect to the priority to be given to the several duties of the Board, the municipal fund shall be applicable to the payment in whole or in part, of the charges and expenses incidental to the following matters within the municipality, namely:—(1) the construction, maintenance, improvement, cleansing and repair of public streets, bridges, embankments, drains, latrines, tanks, wells, and water courses, and the like; (2) the watering and lighting of public streets and places; (3) the construction, establishment and maintenance of schools, hospitals and dispensaries, and other institutions for the promotion of education or for the benefit of the public health, and of rest-houses, sarais, poor-houses, markets, encamping grounds, pounds and other works of public utility, and the control and administration of public institutions of any of these descriptions; (4) grants-in-aid to schools, hospitals, dispensaries, poor-houses, leper

asylums and other educational or charitable institutions; (5) the training of teachers and the establishment of scholarships; (6) the giving of relief and the establishment and maintenance of relief works in time of famine or scarcity; the supply, storage, and preservation from pollu- (7) tion of water for the use of men or animals; (8) the planting and preservation of trees; (9) the taking of a census, the registration of births, marriages, and deaths, public vaccination, and any sanitary measure; (11) the holding of fairs and industrial exhibitions; (12) all acts and things which are likely to promote the safety, health, welfare or convenience of the inhabitants. The purposes for which the municipal funds of the District Municipalities of Burma are applicable are as follow:—Subject to such rules as the Local-Government may make with respect to the priority to be given to the several obligations of the Committee, the municipal fund shall be applicable to the payment, in whole or in part, of the charges and expenses incidental to the undermentioned matters within the municipality, and with the sanction of the Commissioner outside the municipality, when such application of the fund is for the benefit of the inhabitants, namely:—(1) the construction, maintenance, improvement, cleansing and repair of streets and of public bridges, embankments, drains, latrines, tanks and water-courses; (2) the watering and lighting of the streets or any of them; (3) the prevention and extinction of fires; (4) the construction, establishment and maintenance of schools, hospitals, dispensaries, leper asylums and other institutions for the promotion of education, or for the benefit of the public health, and of rest-houses, zayats, wharves, poor-houses, markets, encamping grounds, pounds and other works of public utility, and the control and administration of public institutions of any of these descriptions; (5) grants-in-aid to schools, hospitals, dispensaries, poor-houses, leper asylums and other educational or charitable institutions; (6) the training of teachers and the establishment of scholarships; (7) the giving of relief and the establishment and maintenance of relief works, in time of scarcity or famine; (8) the supply, storage and preservation from pollution of water for the use of men or animals; (9) the planting and preservation of trees; (10) the taking of a census, the registration of births, marriages and deaths, public vaccination and any other sanitary measure; (11) the keeping and auditing of the accounts of the municipal fund, the school fund, and the hospital fund; (12) the holding of fairs and industrial exhibitions; and (13) all other acts and things which are likely to promote the safety, health, welfare or convenience of the inhabitants. The duties of Local Boards of Bombay are as follow:—It shall be the duty of Local Boards, so far as the local fund at their disposal will allow, to make adequate provision for the areas respectively subject to their authority, in regard to the following matters, namely:—(*a*) the construction of roads and other means of communication and the maintenance and repair of all roads and other means of communication vesting in them; (*b*) the construction and repair of hospitals, dispensaries, markets, dharmsalas and other public buildings, and the visiting, management and maintenance of these institutions; (*c*) the construction and repair of public tanks, wells and water-works, the supply of water from them and from other sources, and construction and maintenance of works for the preservation of water for drinking and cooking purposes from pollution; (*d*) the provision of suitable accommodation for the visiting and maintenance of and the training of teachers for primary schools, and the general development and extension of primary education; (*e*) public vaccination and sanitary works and measures necessary for the public health; (*f*) the planting and preservation of trees by the side or in the vicinity of roads vesting in such boards; and (*g*) the maintenance of any property vesting in them. The Local Boards may, at their discretion, provide, out of the said fund, for the following matters, namely:—(*a*) the establishment and maintenance of model farms, the acclimatization of exotics, the importation and distribution of superior kinds of seed, the improvement of the breed of cattle and horses, and the introduction and preservation of fish; (*b*) the establishment and maintenance of relief and local relief works in time of famine or scarcity; and (*c*) any other local works or measures likely to promote the health, comfort or convenience of the public. Subject to the control of the District Local Board, each Local Board shall, within the area subject to its authority, have the control and the administration of all purely local roads, works and buildings maintained at its cost, and also of all local services and institutions except such as the District Local Board thinks fit to take under its own direct control and administration. In respect of roads, works, buildings, services and institutions in the control and administration of the District Local Board, each Taluqa Local Board shall, if the District Local Board so desires, be the agent of the District Local Board and, as such agent, shall exercise such authority and perform such duties as the District Local Board may from time to time in writing delegate to it. The chief provisions in the Bombay Village Sanitation Act of 1889 are as follow:—The Sanitary Committee constituted under this Act may from time to time make rules, and repeal or vary the same, with the approval of the Collector—(*a*) for regulating the terms of office of its members and its proceedings; (*b*) for determining the manner in which its proceedings shall be recorded; (*c*) for

procuring and preserving for the use of the village an adequate supply of pure potable water; (d) for the cleansing of the streets and open spaces of the village; (e) for preventing accumulations of offensive and noxious matter in the village; (f) for preventing nuisances and indecent or insanitary acts or omissions in the village; and (g) generally for giving effect in the village to the purposes of this Act. For the purpose of providing for the village an adequate supply of pure potable water, of cleansing the streets and open spaces thereof, of removing offensive and noxious matter therefrom and for other purposes conducive to the health and comfort of the inhabitants of the village, the Sanitary Committee may utilize, as far as available, the voluntary labour of inhabitants of the village and the services of village servants placed at its command under this Act; and, when these means are insufficient, may from time to time, with the approval of the Collector, employ such servants, enter into such contracts, make such deductions and allowances from any rate leviable under its authority, and may authorize the expenditure by the Collector or under his control, of such sums of money as shall be necessary and reasonable, for the purpose aforesaid. The Sanitary Boards constituted under this Act may, from time to time, make rules, with the approval of the Collector, and, save as hereinafter provided, shall discharge functions and exercise authority for the area subject to its authority in respect of the same matters, in the same manner, and subject to like provisions, restrictions and conditions as are hereinbefore detailed in the case of a Sanitary Committee. The Collector may, subject to the orders of Government, from time to time, appoint a Sanitary Inspector for any area or any part of the area subject to the authority of a Sanitary Board, and also such other subordinates as shall appear necessary, and determine the amount of salary to be paid to each of such officers. He may also dismiss or suspend the said officers. Such Sanitary Inspector may be a person employed by the Taluqa or District Local Board having authority at the place. He may be employed by or on behalf of two or more Sanitary Boards. The Sanitary Inspector shall take measures for preventing breaches of the rules in force in the area for which he is appointed, by, from time to time—(a) posting up and otherwise publishing a general admonition respecting the observance of the said rules; or (b) admonishing any person whom he finds offending against any of the said rules; or (c) summoning to appear before the Sanitary Board any person who, from his own observation or from reports made to him by his subordinates, he has reason to think should be prosecuted for offending against any of the said rules. The Sanitary Inspector shall make such reports and be in such relation to the Sanitary Commissioner consistent with the duties and obligations imposed on him by this Act or arising out of his position as a servant of a Local or Sanitary Board, as Government may prescribe. A Sanitary Board may, with the approval of the Collector, contract with any person—(a) for the daily surface-cleansing of the streets and public spaces within the area or any portion of the area subject to its authority, so far as the same cannot be effected by means of the village-servants, if any, whose services are placed at its command under this Act, or (b) for the removal from the said area of sweepings, dust, ashes, refuse, rubbish, carcasses of dead animals and any offensive or noxious matter. Every Sanitary Board may, with the approval of the Collector, cause to be constructed such works and buildings as shall be necessary for providing for the area subject to its authority or any part thereof—(a) an adequate supply of water; (b) proper and convenient places for the temporary deposit or final disposal of sweepings, dust ashes, rubbish, carcasses of dead animals and other offensive or noxious matter; (c) means for conveying away or removing the several matters and things specified above. In matters pertaining to Sanitation, the duties and powers of the District and Local Boards in Bengal are as follow:—It shall be the duty of every District Board, subject to any rules made by the Lieutenant-Governor under the Act, to provide, so far as may be possible, for the proper sanitation of its district, and to incur such expenses or undertake such liabilities as may be necessary in that behalf. A District Board may, with the approval of, and subject to such limits of cost as shall be imposed by the Commissioner, provide any place within its district with a proper and sufficient supply of water, and for this purpose may—(1) construct, repair and maintain water-works, wells or tanks, and do any other necessary acts; (2) take on lease or hire any water-works and purchase any water-works, or any water, or right to take or convey water, either within or without its district; and (3) contract with any person for a supply of water. A District Board may, with the sanction of the Lieutenant-Governor, contribute such annual or other sum as may be agreed upon towards the cost of—(a) the construction, repair and maintenance, under the provisions of the Bengal Municipal Act, 1884, of water-works, wells or tanks within the district, or (b) taking measures under the said Act for the prevention of plague in the district; provided that no application for such sanction shall be made unless it is authorized by a resolution which has been passed at a meeting specially convened for the purpose and in favour of which a majority of not less than two-thirds of the total number of members of the District Board have voted. All streams, channels, water-courses,

tanks, reservoirs, springs and wells situated within the district, and not being private property or under the control of any officer of the Government, shall, for the purposes of this Act, be under the control and administration of the District Board. The District Board may, by an order duly published at such places and in such manner as it may deem fit, set apart convenient tanks, parts of rivers, streams or channels situated within the district, and not being private property or under the control of any officer of the Government, for the supply of water for drinking and culinary purposes; and, from the date of publication of such order, such tanks, parts of rivers, streams or channels shall be held to be public springs or reservoirs. Every District Board shall appoint, to be members of a Sanitation Committee, not more than five nor less than three members of the Board. The Civil Surgeon of the district shall be a member ex-officio of the Sanitation Committee of his district. It shall be the duty of a Sanitation Committee, subject to the control of the District Board and to any rules made by the Lieutenant-Governor, to initiate and supervise works connected with the sanitation of the district, and to exercise such of the powers of the District Boards as may be delegated to it in accordance with the Act. The District Board shall also appoint a properly qualified person to be its Sanitary Inspector, fix the salary of such Sanitary Inspector and the details of the establishment subordinate to him. Every Union Committee shall subject to the control of the District Board, and in accordance with rules made by the Lieutenant-Governor under this Act—(1) provide, as far as possible, for the sanitation and conservancy of the union and the prevention of public nuisances therein ; (2) make special arrangements for the sanitation and conservancy of fairs and melas held within the union; (3) have control of all drains and other conservancy works within the union which are not under the control of any other authority; and, (4) execute all works which are necessary for improving the sanitation, conservancy or drainage of the union : provided that the district board may itself undertake any such work which, by reason of its magnitude, or of the amount of expense likely to be incurred thereon, cannot in the opinion of the District Board, be satisfactorily executed by the Union Committee. If it appears to the Union Committee that, for any reason, it is necessary to improve the sanitary condition of any village or part of a village within the union, the Committee may, in accordance with a scheme approved by the District Board and sanctioned by the Commissioner under rules made by the Lieutenant-Governor under this Act—(*a*) cause huts or privies to be removed, either wholly or in part ; (*b*) cause private drains to be constructed, altered or removed ; (*c*) cause streets, passages and public drains to be constructed or widened; (*d*) cause tanks or low lands to be filled up or deepened ; and (*e*) cause such other improvements to be made as, in its opinion, are necessary to improve the condition of such village or part. The Union Committee may, by written notice—(i) require the owner or occupier of any hut, or the owner of any privy, to remove such hut or privy, either wholly or in part ; or (ii) require the owner or occupier of any building to construct private drains therefor, or to alter or to remove private drains thereof, within a period to be specified in the notice. If any work required by any such notice is not executed within the period specified in the notice, the Union Committee may themselves cause such work to be carried out. All expenses incurred by the Union Committee, including such reasonable compensation as the Committee may think fit to pay to the owners or occupiers of huts or privies removed, shall be met out of the union fund. The Union Committee may, with the sanction of the District Board, employ a special establishment for the cleansing of any village within the union. (2) If any village appears to the Union Committee to be in a filthy condition, the Committee may, by written notice, require the persons who occupy buildings in the village to cleanse their holdings, to the satisfaction of the Committee, within a period to be specified in the notice. If any person on whom notice has been served fails to comply with the requisition contained in the notice, the Union Committee shall, unless reasonable cause to the contrary is shown, cause his holding to be cleansed, and recover from such person such portion of the costs of such cleansing as may be approved by the Sanitation Committee, as if the same were an arrear of the assessment imposed under the Act. The Union Committee may, subject to rules made by the Lieutenant-Governor under this Act, by written order,—(*a*) direct, in accordance with a scheme approved by the District Board and sanctioned by the Commissioner, in respect of any village, that no building which it is proposed to erect in such village, and no addition to any existing building therein, shall be placed in advance of an alignment to be prescribed by the Committee and demarcated on the ground, and (*b*) prescribe, in accordance with the said scheme the space which shall intervene between each new building, and between new buildings and any road in the village. Where any building, or any addition thereto, has been placed in contravention of an order passed by the Union Committee, the Union Committee may apply to the District Magistrate, and such Magistrate may make an order—(i) directing that the work done, or so much of the same as has been executed in contravention of orders and rules be demolished by the owner of the building or altered by him to

the satisfaction of the Committee, as the case may require, or (ii) directing that the work done, or so much of the same as has been executed in contravention of the order and rules be demolished or altered by the Union Committee at the expense of the owner: provided that the Magistrate shall not make any such order without giving the owner and occupier full opportunity of adding evidence and of being heard in defence. If any person to whom a direction to demolish or alter any building is given fails to obey the same, he shall be liable to fine which may extend, in the case of a masonry building, to one hundred rupees, and, in the case of any other building, to twenty rupees, and to further fine which may extend, in the case of a masonry building, to ten rupees, and, in the case of any other building, to two rupees, for each day during which he so fails after the first day. A Union Committee may provide the union, or any part thereof, with a supply of water proper and sufficient for public and private purposes; and, for this purpose may—(*a*) construct, repair and maintain tanks or wells, clear out streams or water-courses, and do any other necessary acts; (*b*) with the sanction of the District Board, purchase or acquire by lease any tank, well, stream or water-course, or any right to take or convey water, within or without the union; (*c*) with the consent of the owner thereof, utilise, cleanse or repair any tank, well, stream, or water-course within the union, or provide facilities for obtaining water therefrom; (*d*) deal with any tank, well, pool, ditch, drain or place containing or used for the collection of, any drainage, filth, stagnant water, or matter likely to be prejudicial to health, by draining or cleansing it, or otherwise preventing it from being prejudicial to health, but not so as in any case to interfere with any private right; or (*e*) contract with any person for a supply of water. When a Union Committee has, with the consent of the owner, cleansed or repaired, or provided facilities for obtaining water from any tank, well, stream or water-course, the same shall, subject to any rights retained by the owner with the concurrence of the Committee, be reserved for drinking and culinary purposes, and shall be kept open to access by the public. Any tank, well, stream or water-course which a Union Committee may construct, repair or maintain, or purchase or acquire by lease, shall remain under the control and administration of the Union Committee; and the Committee may, by order duly published in the village or villages in which such tank, well, stream or water-course is situated, set apart the same, or, any other tank, well, stream or water-course within the union, for the supply of water for drinking and culinary purposes. The duties of the Local Boards of Madras are as follow:—Every Local Board shall, subject to such rules as may from time to time be prescribed by the Governor in Council, and so far as the funds at its disposal may admit, provide within the areas under their authority or with the special sanction in each case of the Governor in Council without the said areas for the following purposes:—(i) the construction, repair and maintenance of roads, bridges and other means of communication; (2) the planting and preservation of trees on sides of roads and on other public places; (3) the construction, maintenance and repair of hospitals, dispensaries, lunatic asylums, choultries, markets, slaughter-houses, cart-stands, drains, sewers, latrines, water-works, tanks and wells, the payment of all charges connected with the objects for which such buildings have been constructed, the training and employment of medical practitioners and vaccinators, the sanitation of towns and villages, the cleansing of the streets, drains, sewers, latrines, tanks and wells and other works of a similar nature; (4) the diffusion of education, and, with this view, the construction and repair of school-houses, the establishment and maintenance of schools, either wholly or by means of grants-in-aid, the inspection of schools and the training of teachers; (5) the establishment and maintenance of relief-works in time of famine or scarcity; (6) other measures of local public utility calculated to promote the safety, health, comfort or convenience of the people; (7) the payment of salaries, leave-allowances, pensions, gratuities and compassionate allowances to servants employed by the Local Board; (8) the payment of any amounts falling due on any loans legally contracted by the Local Board. The duties of the District and Local Boards of Punjab are as follow:—(1) The following matters shall, subject to such exceptions and conditions as the Local Government may make and impose, be under the control and administration of each District Board within the area subject to its authority:—(*a*) the management of all property vested in the District Board; (*b*) the construction, repair and maintenance of public roads and other means of communication; (*c*) the establishment, management, maintenance and visiting of public hospitals, dispensaries, sarais and schools, and the construction and repair of all buildings connected with these institutions; (*d*) the training of teachers and the establishment of scholarships; (*e*) the supply, storage and preservation from pollution of water for drinking, cooking and bathing purposes; and (*f*) the planting and preservation of trees. (2) The Local Government may direct that any of the following matters shall, subject to such exceptions and conditions as it may make and impose, be under the control and administration of a District Board within the area subject to its authority:—(*a*) the management of any property vested in Her Majesty; (*b*) the establishment, maintenance, visiting

and management of markets, rest-houses, encamping grounds and other public institutions, and the construction and repair of all buildings connected with these institutions; (c) the construction and repair of embankments, and the supply, storage and control of water for agricultural purposes; (d) the preservation and reclamation of soil, and the drainage and reclamation of swamps; (e) the construction, repair and maintenance of famine-preventive works, and the establishment and maintenance of such relief-works, relief-houses and other measures in time of famine or scarcity as may be entrusted to the charge of the Board by the Local Government; (f) the registration of births, marriages and deaths; (g) fairs and agricultural shows and industrial exhibitions; (h) any other local works or measures likely to promote the health, comfort, convenience and interests of the public or the agricultural or industrial prosperity of the country; and (i) any other matters which the Local Government may declare to be fit and proper matters to be taken under the control and administration of the Board. (3) The Local Government may cancel or modify any direction given by it under the Act. (4) A District Board shall, so far as the funds at its disposal permit, make due provision for all matters placed under its control and administration by or under the Act. The Local Government, or, subject to the control of the Local Government, a District Board, may direct that, within the area subject to the authority of a Local Board, any matter placed under the control and administration of the District Board shall be transferred to its control and administration of the Local Board. A Local Board, as the agent of, and subject to the control of, the District Board, shall, so far as the funds at its disposal permit, make due provision for all matters transferred to its control and administration. It shall be the duty of the District Board to enforce the responsibility imposed on a Local Board. The duties of the District Councils and Local Boards of Central Provinces are as follow:—The following matters shall subject to such exceptions as the Chief Commissioner may, from time to time, by order in writing, make, be under the control and administration of the District Council and of the Local Boards within the areas subject respectively to their authority:—(a) the construction, repair and maintenance of roads and other means of communication; (b) the management, maintenance and visiting of schools, hospitals, dispensaries, markets, rest-houses, sarais and other public institutions, and the construction and repair of all buildings connected with these institutions; (c) the construction and repair of public wells, tanks and water-works, the supply of water from them and from other sources, and the preservation from pollution of water for drinking and cooking purposes; (d) the planting and preservation of trees on public grounds; (e) the establishment and maintenance of relief-works in time of famine or scarcity; (f) any other local works or measures likely to promote the health, comfort or convenience of the public: and (g) the maintenance of any building or other property, vested under this Act in the District Council. Relations of Local Boards to District councils:—A local board as the agent of and subject to the control of, the District Council, shall, within the area subject to its authority, have the control and administration of, and be responsible for, all the matters except such of those matters as the District Council may think fit to take under its direct control and administration, and such as the Chief Commissioner may have excepted by order. It shall be the duty of the District Council to enforce the responsibility imposed on, by a Local Board. The duties of Local Boards of United Provinces of Agra and Oudh are as follow:— Every Board, shall, so far as the funds at its disposal will permit, but subject to such exceptions and conditions as the Local Government may make and impose, provide for the control and administration of the following matters within the district:—(a) the construction, repair and maintenance of public roads, bridges and other means of communication; (b) the planting and preservation of trees on the sides of roads and on other public grounds; (c) the establishment, management and maintenance and visiting of hospitals, dispensaries, poor-houses, asylums, veterinary hospitals, markets, staging-houses, inspection-houses, public-parks and gardens, and other public institutions and the construction and repair of all buildings connected with these institutions; (d) the construction and repair of school houses and all appurtenant buildings, the establishment, management and maintenance of schools, either wholly or by means of grants-in-aid, the inspection of schools, the training of teachers and the establishment of scholarships; (e) the construction and repair of public-wells, tanks, water-works, canals, embankments and drainage-works and the supply of water from them and from other sources; (f) the construction and maintenance of light railways; (g) the construction, repair and maintenance of famine preventive works, the establishment and maintenance of relief works and relief houses and the adoption of such other measures of relief in time of famine and scarcity as may be considered necessary; (h) the institution, holding and management of fairs, agricultural shows and industrial exhibitions, the breeding and medical treatment of cattle, horses and other animals and all measures tending to the improvement and assistance of agriculture and industries; (i) the maintenance of any building or other property which is vested under this Act in the Board or may be placed by the Local Government

under the management of the Board; (j) the management of any public or private charities or trusts placed, by the order or with the consent of the Local Government, under the Board; and (k) public vaccination, village sanitation and any other local works or measures likely to promote the health, comfort, convenience or interest of the public. A Board may also with the sanction of the Local Government and if directed by the Local Government, it shall, to the extent so directed—(a) unite with any other Boards in works or undertakings which benefit all the districts of which the Boards so unite; and (b) contribute to any work or institution from which the district benefits, although such work or institution is undertaken or maintained outside the district.

*Rules Regulating The Constitution And Functions Of The Madras Sanitary Board: As In Force On The 1st April 1916.

1. The Sanitary Board shall consist of three members, namely:—(1) The Chief Engineer, Public Works Department. (2) The Surgeon-General. (3) The Secretary to Government in the Local and Municipal Department. 2. The Chief Engineer, Public Works Department, shall be the President of the Board, and Deputy Chief Engineer, Public Works Department, shall be its Secretary. 3. Subjects submitted for the consideration of the Sanitary Board shall be considered either in meeting or by circulation of the correspondence. 4. The President may call a meeting of the Board whenever he considers it desirable, and shall do so on the request of either of the other members. 5. The proceedings of the Board shall be in the form of resolutions. Resolutions of the Board shall, prior to issue, be circulated to all members, but the President may, in cases of urgency, direct the Secretary to issue a resolution prior to such full circulation, the papers being fully circulated as soon after as possible. 6. In the event of a difference of opinion among the members of the Board, the decision of the majority shall prevail. But any member may record a minute of dissent and may require that the same shall be submitted, with a copy of the resolution to which it relates, for the orders of Government, and the President shall forthwith submit the same with such remarks as he may have to offer. 7. All resolutions of the Board shall be signed by the Secretary. 8. The President may, through the Secretary, call for such information from Local Bodies and Government Officers as may be necessary in order to elucidate matters which have to be laid before the Board. All such references shall be made in letter form, and not by proceedings. 9. All communications to the Sanitary Board, except those made by Government shall be addressed to the Secretary. The Government will address the Board direct. 10. All plans and estimates for any Municipal sanitary work shall, if the amount of the estimate exceeds Rs. 500, but does not exceed Rs. 2,500, be submitted by the Municipal Council for the sanction of the Sanitary Engineer. All plans and estimates of any Local Fund sanitary work shall, if the amount of the estimate exceeds Rs. 2,500, be submitted by the Local Board for the sanction of the Sanitary Engneer. Explanation.—(i) The limit of Rs. 2,500 laid down in this rule does not include the cost of site. (ii) The term sanitary work includes (1) hospitals, dispensaries, markets, slaughter houses, latrines, incinerators, urinals and cesspools; (2) works connected with water-supply; (3) works relating to drainage. (iii) The above rule does not apply to repairs which do not involve any important structural alterations or to works included in famine programmes. 11. Whenever it is proposed by any Local Board or Municipal Council to make any considerable improvements in existing village-sites, or to lay out new sites, or whenever it is proposed to grant house-sites near railway stations, such proposals shall first be submitted to the Sanitary Commissioner for approval. 12. Standard plans for sanitary works included in class 1 of explanation (ii) to rule 10 shall be issued by the Sanitary Board and distributed, with detailed estimates, to Presidents of District Boards and Chairmen of Municipal Councils for guidance. These plans and estimates will be prepared by the Sanitary Engineer and forwarded by him to the Sanitary Commissioner, who will then submit them to the Sanitary Board for approval. 13. When any sanitary work falling under rule 10 is contemplated by any Local Board or Municipal Council, it shall apply to the Sanitary Board for advice as to the standard plan most suitable for the purpose and the Sanitary Board shall advise accordingly. 14. (1) All plans and estimates for works of a sanitary nature, costing Rs. 10,000 or less, shall be prepared by Local Bodies in consultation, in all matters of importance, with the District Medical and Sanitary Officer. (2) In the case of District and Taluk Boards, they shall be signed or countersigned by the District Board Engineer in token of their accuracy in all respects. (3) In the case of Municipalities possessing an Engineer officer, they shall be prepared and signed by that officer. (4) In the case of Municipalities which do not possess an Engineer officer, they shall be sent for scrutiny and countersignature either to the District Board Engineer or to the Executive Engineer of the Public Works Department, the Municipality paying the prescribed fee. (5) Plans and estimates costing upwards of Rs. 10,000 shall be prepared by the Sanitary Engineer.

Note.—Nothing in this rule shall prevent Local Bodies from preparing estimates on standard plans to any amount. They may also prepare plans and estimates exceeding Rs. 10,000 if the component parts are of similar design, *e.g.*, a market with three similar sheds costing, say, Rs. 3,400 each. 15 Plans and estimates for works costing over Rs 2,500, but not over Rs. 10,000, shall, unless they relate to any Local Fund work following a type-design after approval by the Local Board or Municipal Council concerned, be sent to the Sanitary Commissioner who will note his opinion thereon with sole reference to the sanitary points involved and forward them to the Sanitary Engineer. If the Sanitary Commissioner and the Sanitary Engineer agree as to these points, the Sanitary Engineer will accord professional sanction to the estimates. In case of disagreement between the Sanitary Commissioner and the Sanitary Engineer as to any such point, the latter shall make a reference to the Sanitary Board who will deal with the matter under rule 16. 16. Plans and estimates costing over Rs. 10,000, shall be sent to the Sanitary Commissioner who will note his opinion thereon on the sanitary aspects only and forward them to the Sanitary Board (*a*) through the Sanitary Engineer if they have been prepared by Local Boards or (*b*) direct if they have been prepared by the Sanitary Engineer provided that in the latter case he may, if he considers it necessary in any particular case, return them to the Sanitary Engineer for further scrutiny or revision. In that event the Sanitary Engineer will scrutinize the plans and estimates, complete them in the form finally decided upon and forward them to the Sanitary Board. If the Sanitary Board approves of the estimate and if the amount does not exceed Rs. 20,000, the Board shall return it to the Sanitary Engineer for professional sanction. If the Sanitary Board does not approve of the estimate, it may either cause it to be revised by the Sanitary Engineer or may return it for revision to the Local Body concerned. If the amount of the estimate as finally approved by the Sanitary Board exceeds Rs. 20,000, the plans and estimates shall be submitted to Government for sanction through the Chief Engineer. 17. The Sanitary Engineer will have the powers of a Superintending Engineer and will under paragraph 311 (*a*) of the Public Works Code, be empowered to accord professional sanction to estimates up to Rs. 20,000. 18. If a Local Board or a Municipal Council or other authority objects for financial or other reasons to adopt a design or an estimate prescribed by the Sanitary Board, it shall apply to Government for orders. 19. The President of any Local Board or Municipal Chairman may, at any time, address the Sanitary Engineer or Sanitary Commissioner regarding any advice required in connection with any sanitary work. 20. It is the duty of the Sanitary Commissioner from time to time to bring to the notice of Government or of the Sanitary Board cases where the need of water-supply or drainage schemes is specially indicated. Such needs may also be brought to the notice of Government from other sources. Where such needs are recognised by the Government or the Sanitary Board, orders will be passed to include them in a register of schemes in regard to which preliminary reports are to be submitted to the Sanitary Board under this rule. This register, copies of which will be maintained by the Sanitary Commissioner and by the Sanitary Engineer, will record a field of work for preliminary enquiry, and will enable the Government to pass special directions, if need be, in regard to the order of urgency in which this preliminary work is to be dealt with. Orders to include a scheme in the register will imply that the Sanitary Engineer is to draw up, in consultation with the Sanitary Commissioner and the Local authorities, a preliminary report for a feasible scheme or for alternative schemes giving the general outlines of each. In the case of water-supply schemes information should be furnished as to the source and quality and probable quantity of supply and the method of distribution. In the case of drainage schemes, information should be furnished as to the general features, such as the extent to which pumping will be necessary, or any special system of disposal of sewage by sewage farm or otherwise. In every case, the approximate cost should be stated. Too much detail should be guarded against and only such items of information supplied as will enable the authorities to decide whether the scheme is such as will warrant the preparation of detailed plans and estimates. The reports will be submitted by the Sanitary Engineer through the Sanitary Commissioner and signed by both officers. If on any point there is a divergence of opinion between these officers, a free expression of the opinion of each should be submitted for orders of the Sanitary Board with the report. The orders passed by Government on these preliminary reports will be recorded in the register so that the schemes, if approved, may be brought to the Sanitary Engineer's annual programmes of work for detailed investigation and estimates in due course. Detailed plans and estimates for schemes of water-supply and drainage estimated to cost over Rs. 10,000 will never be drawn up without the specific orders of Government. 21. The Sanitary Engineer will, in concert with the Sanitary Commissioner, draw up and submit to the Sanitary Board, so as to be received not later than the 28th February annually, a statement of the larger sanitary works with which he proposes to deal in the following official year. This list shall, after approval

by the Board, be submitted for the orders of Government. 22. Every Local Board or Municipal Council, which has, during any calendar year submitted any estimate to the Sanitary Board and received the Sanitary Board's order thereon, shall submit to the Sanitary Board not later than the 31st January of the year following a statement showing the subject and amount of the estimate, the number and date of the Sanitary Board's resolution passing orders thereon, the present position of the work whether executed, under execution or otherwise, and information as to the cause of delay if the execution of the work has not been completed. 23. The Sanitary Commissioner and the Sanitary Engineer shall each prepare an annual report of the work of his department during the preceding calendar year and shall submit it to the Sanitary Board so as to be received by it not later than the 1st April annually. The Sanitary Board shall submit these reports, together with its own, to Government so as to be received by the 15th May in each year. 24. The Sanitary Commissioner and the Sanitary Engineer may address Government on matters unconnected with the Sanitary Board's work as laid down above in their respective capacities as heretofore, and may communicate direct with Government or Local Bodies in regard to—(1) Matters of routine. (2) The status, discipline and promotion of, and the conduct of their duties by, their own subordinates. (3) In the case of the Sanitary Commissioner, the sanitary state of works, inspection notes, arrangements for improved sanitation, etc. (4) In the case of the Sanitary Engineer, the execution of works not being or to be carried out by the Department of Public Works and arrangements with Local Boards and Municipal Councils in reference thereto, or the after maintenance of such works. (5) Reports required by Government.

Syllabus In Minor Sanitary Engineering.

For a five months' course in the Sanitary Engineer's Office, Madras, the Syllabus prescribed by Government is as follows:—General:—The use of drawing instruments. The use of scales. The reading of plans and sections. The calculation of gradients. Chain surveying and the practical use of levelling instruments. The measurement of areas and volumes including the calculation of small quantities of earth-work, brick-work, masonry, etc. Estimating for minor and temporary works. Buildings:—The description of soils and strata best suited for the erection of buildings in respect to stability and healthiness of the dwellings erected thereon. The necessity for foundations, their proper depth, etc. Knowledge of the various building materials, such as brick, stone, lime, surki, asphalt, paints, etc. Their quality and the possible influence of the atmosphere on them. Their suitability for use in various parts of a building. To distinguish between good and bad brick, timber, lime, cement, etc. The methods of ventilation applicable to Indian conditions. Main details of the construction of permanent and semi-permanent hospital wards as gained from a study of plans. The area and cubic space required in ordinary and contagious wards. The details of design of latrines as gathered from a study of plans—permanent and temporary. Details of nightsoil depots and a knowledge of method of trenching, covering, etc. Water-supply:—The inspection of sources of supply and determination by inspection as to their suitability for dietetic purposes. The proper construction of wells to prevent the inlet of surface polluted water. The calculation of the capacity of a well and the average supply of water likely to be obtained from it. Methods of filtering and purifying small quantities of water or of otherwise rendering it safe for domestic use. The method of drawing samples of water for chemical examination from water taps, tanks, and streams. Simple methods of calculating the discharge of small channels. The various methods of raising water used in India and the construction of the ordinary lift and force pumps. The use and construction of small cisterns and tanks for the storage of water. The quantity of water necessary per diem per head for a town population, and for horses and other animals. The method of driving tube wells, their use, and the position in which suitable. Drainage:—The materials used in drainage works. The use of drainage pipes, glazed and unglazed, brick drains, syphon traps, cesspools, septic tank, etc. The various methods of house and street drainage. Knowledge of methods for the rough determination of the discharging capacity of an open drain, channel, closed pipe and sewer. The proper gradients for drains of varying sizes. The various methods of pipe-jointing in closed drainage and sub-soil drainage. The variation in sub-soil water-level and its effect on health. The methods of excluding sub-soil water from areas and spaces below ground level. The methods of flushing and cleaning drains, and of drain testing. Disposal of sewage, etc:—Methods of sewage purification. The action of the septic tanks, bacterial and other filters, and of land, etc. The relation of the septic tank to the old cesspool. Simple plant for domestic sewage disposal. The formation of small collecting tanks and areas for sewage filtration. The proper crops to grow under sewage irrigation. The sub-soil drainage of sewage farms, when necessary and when not. The maximum area which can be irrigated by any quantity of sewage. The maximum amount of sewage which can be put in an area to ensure a maximum return in relation to

temperature and climate. No candidate will be admitted to the examination unless he produces a certificate signed by the Sanitary Engineer or the Personal Assistant to the Sanitary Engineer that he has undergone a five months' course in Minor Sanitary Engineering. The examination shall comprise—(1) a written examination, and (2) a practical and *viva voce* examination. The distribution of marks and the minima required for passing shall be as follows :

	Max.	Min. for passing. 1st class.	2nd class.
Written examination (three hours).	50	25	20
Practical and *viva voce* examination.	50	25	20
Total ...	100	60	45

The practical examination will be thorough and may involve as much as five hours' work on the part of candidates. 15 of the 50 marks will be allotted for the *viva voce* portion of the examination. For the special course of eight weeks at the Medical College, Madras, in Advanced Minor Sanitary Engineering for Assistant Surgeons qualifying for the post of Sanitary Assistants and Second Class Health Officers, the syllabus prescribed by Government is as follows :—Drawing :—Use of drawing instruments, scales and accessories, making dimensioned sketches from actual objects and models ; preparation of simple drawings from sketches and specifications; reading of plans and sections including plotted sections of levels and gradients. Estimating :—Mensuration of simple surfaces and solids, calculation of gradients ; quantity surveying, estimating and drawing out detail specifications for minor and temporary works. Buildings :—Sites and materials; construction of ordinary and special buildings, both permanent and temporary ; their details from study of plans ; opening up of congested areas ; planning of village and town extensions. Practical study by visits to sanitary works comprising slaughter-houses, medical institutions, markets, latrines, dhobikhanas, conservancy depots, trenching ground, etc. Municipal by-laws relating to house construction. Water-supply:—The various schemes; general principles governing their design ; data for preliminary proposals ; construction of wells, tanks, tube-wells and borings ; calculation of capacities ; determination of yield from springs and discharge from channels and small streams. Various methods of lifting water with details of appliances used ; construction of small cisterns and tanks for storage of water ; pipes and fittings. Practical study by visits to at least three water-works in operation. Inspection of at least three villages to study practically existing methods of water-supply and suggestions for improved water-supplies. By-laws relating to water-supply. Drainage :—Description and comparison of the various systems ; general principles governing their design ; data for preliminary proposals ; drainage materials and their use ; proper construction of drains, testing and maintenance of drains. Practical study by visits to at least two drainage works in operation. Practical make-shift methods of sewage disposal and drainage works for small quantity of sewage. Disposal works. By-laws relating to drainage.

DRAWING: THE USE OF DRAWING INSTRUMENTS, SCALES AND ACCESSORIES.

Drawing.

Drawing is the language of the engineer and the estimate is considered the language of the financier. In the present-day system of gene ' education in High Schools, prominence is now oeing given to drawing, free hand and outline, and with drawing instruments. It is only now that a beginning is being made in this country to create an interest in the art of Drawing by the inclusion of Drawing as one of the subjects in the curriculum of studies in our High Schools. In the Elementary Grammar schools at Home, Drawing is being taught as a compulsory subject and if we compare the progress of knowledge in the art of Drawing in this country with that of England it will be seen that the former is half a century behind the latter. As England progresses in this art of drawing day after day at a fast rate and as we are 50 years behind England and as our rate of progress is slower than that of England, we will ever be much behind England in this art. However this may be, there is no reason to view the situation with a spirit of despondency. The art of drawing may, in my opinion, be divided into two stages, *viz.*, 1. the stage of necessity and 2. the stage of luxury. We should appreciate the importance of drawing and aim at reaching the stage of necessity by steady and continued progress. It is immaterial how far we are behind other countries in the second stage of luxury. I will describe therefore, in this lecture the elementary essentials of plan-drawing.

Drawing Papers.

The Drawing papers known as Whatman's are the best prepared of any obtainable and they are almost universally employed. The following are the usual sizes in inches of drawing papers:—Demy 20 × 15½; Medium 22 × 17; Royal 24 × 19½; Super-royal 27 × 19; Imperial 30½ × 22: Columbier 34 × 23; Atlas 34 × 26; Double elephant 40 × 27; Antiquarian 53 × 31; Extra antiquarian 56 × 38.

Drawing Instruments.

A list of Drawing instruments used in the Madras P.W.D. is given below:—

	Per		Rs.	A.	P.
Instrument, mathematical, 1st class,	Box	...	63	11	6
Do. 2nd do.	"	...	38	0	11
Do. 3rd do.	"	...	25	7	1
Instrument, mathematical, 3rd class in fish skin case, large	Case	...	16	11	10
Do. do. small	"	...	4	6	10
Rule, parallel, brass, rolling, 24 ins. each		...	24	5	5
Do. do. 18	"	...	16	13	0
Do. do. 15	"	...	14	9	8
Do. do. 12	"	...	12	6	3
Do. do. 8	"	...	14	2	7
Do. do. 6	"	...	10	9	0
Scale, plotting, boxwood, 6 in a set with off-sets	Set	...	7	13	1
Straight edge, graduated in feet, inches and tenths	Each	...	18	9	4
Decimal scales with off-sets ...	Set	...	2	1	0
Set squares, vulcanite, Stanley's, 8 inches long, 1 to 1 slope ...	Each	...	1	2	11
Do. , 2 to 1 slope	"	...	1	2	11

Use Of Drawing Instruments.

It may here be stated that a detailed description of the use of drawing instruments is not given in books on drawing on the presumption that the use of these instruments is "familiar" to all. As far as you are concerned, I know that you are not 'familiar' with the use of mathematical instruments. I will give therefore a short description of the use of the common instruments. 1. Compass with plain-point:—For measuring lengths of more than 1 inch and less than 6 inches on scales and setting them off on drawing sheet. In practice the dimensions are marked on drawing paper direct with the scales. If any dimension is required of a completed drawing, it is measured by the compass and the measurement is read from the scale of the drawing. 2. Compass with pencil point:—For describing in pencil arcs or circles the diameters of which are between 3¾ inches and 8½ inches. 3. Compass with ink point:—For describing in ink arcs or circles the diameters of which are between 1½ inches and 8½ inches. 4. Lengthening bar of compass:—For describing arcs or circles of diameter between 8½ inches to 13 inches by attaching same to the shifting leg of the compass. 5. Hair divider:—For measuring distances with greater delicacy than is possible with the compass. 6. Pencil sweep:—For drawing arcs or circles in pencil the diameter of which is between ⅝ or ¾ of an inch and 3¾ inches. 7. Ink sweep:—For drawing arcs or circles in ink the diameter of which is between ¾ of an inch and 1⅞ inches. 8. Spring bow divider:—For setting off distances up to ¾ of an inch. 9. Spring pencil bow:—For describing arcs or circles in pencil between 1/40 of an inch to ⅝ of an inch in diameter. 10. Spring ink bow:—For describing arcs or circles in ink between

1/40 of an inch to $\frac{3}{4}$ of an inch in diameter. 11. Drawing pen :—For drawing in ink straight lines. 12. Proportional compass :—For reducing or enlarging drawings in any given proportion either superficial or solid. 13. Knife key :—For bringing the black lead pencil to a fine point, for mending pens, cutting pencils, for tightening and loosening the pivot of compass, and for screwing and unscrewing the screws at the knee joints of the compass. 14. Key,—For tightening and loosening the pivot of compass, and for screwing and unscrewing the screw in the knee-joints of the compass. 15. Six inches parallel ruler :—For drawing parallel lines up to 6 inches. 16. 45° set square :—For drawing straight lines making with the base angles of 90° and 45° and parallel lines. 17. 60° set square :—For drawing straight lines making with the base angles of 90° and 60° and 30° and parallel lines. 18. French curve :—For drawing curved lines which cannot be drawn with the compasses. 19. Protractor :—For measuring angles and for laying down angular lines to a base line on a drawing paper and also for measuring off distances from scales which are marked on protractors with the aid of compasses or bows. 20. Sector :—This instrument which is supplied with first class mathematical instrument boxes is usually kept as a kind of established ornament. Practically its use is extremely limited. Nevertheless it is an ingenious instrument and the description of its practical uses would occupy many pages and I will therefore mention here that this instrument may be used to divide the circumference of a circle into any number of equal parts from 4 to 12 and for obtaining the diminishing proportion of chords, tangents, and secants, etc. 21. Rolling parallel ruler :—For drawing parallel lines. 22. Straight edge :—For drawing long straight lines. 23. Plotting scales :—For marking off distances in drawings. The uses of the different scales will now be described.

Scales.

In actual practice it would be impossible to make a drawing to full size of every object which we desire to show in a drawing. It is therefore necessary to draw the plans or maps to what is termed "to scale" *i.e.*, each line in the plan is made with a fixed and known proportion to the line it represents. In a drawing, drawn to scale, if one line one inch long represents a line of 100 feet of any object then the scale of the drawing is said to be "one inch equals 100 feet." In other words the drawing represents the object to a size of $\frac{1}{1200}$. This is termed the representative fraction of the drawing, the numerator being always 1 (inch) and the denominator being the actual length of the object in inches represented by 1 inch in the drawing. In books on drawing the statement is made that "representative fraction" or the proportion of the drawing to the actual object *should* be entered in a conspicuous place on *every* plan. This is never done in practice and no useful results would be achieved by entering on the plan the 'representative fraction.'

DRAWING: READING OF PLANS AND SECTIONS INCLUDING PLOTTED SECTIONS, LEVELS AND GRADIENTS.

Plans.

Having stated that objects are represented on drawings to proportional sizes as may be required, let me now lead you to the practical application of this statement by first defining the expression 'plan.' A plan is a representation drawn on a plane, as a map or a chart. Thus then, a plan is a general term for any graphic representation. In practice, the word is also commonly employed for a representation or delineation of a horizontal section of anything as of a building. For the present, I use the word 'Plan' in the general sense representing any drawing. Plans may be divided into the following classes :—1. Plans of surveys. 2. Plans of level sections. 3. Plans of buildings. 4. Plans of machines, engines and other appliances.

Survey Plans.

As regards plans of surveys the different maps which are available for sale, with particulars as to scale, use, etc., are shewn below :—

Serial No.	Description.	Scale 1 inch =	Remarks.
1	Maps published according to Acts of Parliament.	6 miles 4 miles 1 mile	Useful for exploring the country. A specimen is illustrated in plate 1.
2	District maps ...	8 miles 4 miles 2 miles	Useful for exploring the country. A specimen is illustrated in plate 2.
3	Taluk maps ...	2 miles 1 mile	Useful for exploring the country. A specimen is illustrated in plate 3.
4	Village maps ... Proprietary village maps ...	660 ft. 330 ft. 1320 ft.	Useful for general index plans of irrigation and water supply schemes. A specimen is illustrated in plate 4.
5	Town maps ...	528 ft. 264 ft. 132 ft. 66 ft.	Maps of towns of scales 1 inch = 528 and 1 inch = 264 ft. are useful for index plans of water supply and drainage works. Town maps showing the whole area of a town to one scale one inch = 132 ft., or one inch = 66 ft., are not available. These maps are useful for details of water supply and drainage schemes. A specimen is illustrated in plate 5.

Maps 1 to 5 may be had coloured or uncoloured free of cost on the public service and for cash on private requests. In the Presidency of Madras, applications should be made to the Director of Surveys, Chepauk, Madras, for District and Taluk maps, to the Collectors or Tahsildars for village maps, to Chairmen of Municipal Councils for mofussil Town maps, and to the Deputy Collector of Madras for Madras City maps. The prices of District and Taluk maps depend on :—1. size of maps; 2. whether coloured or uncoloured; 3. whether mounted or unmounted. For an uncoloured and unmounted District or Taluk map the general average price is Rs. 2. The price of a village map depends upon the area and the number of sheets subject to a minimum price for each complete village irrespective of the number of sheets as shown below :—

Area in acres.		Price per sheet.	Minimum charge for the whole map of one village irrespective of number of sheets.
From	To	Annas.	Annas.
Under	1,000		4
1,000	1,500		6
1,500	2,000		8
2,000	3,000		10
3,000	4,000		12
4,000	5,000		14
5,000	5,500		16
Above	5,500		

Taking the case of a village the area of which is 3050 acres and is shown in 5 sheets the cost of the village map will be 12 annas and not 5×2 or 10 annas. Taking another case of a village of same area of 3050 acres but shewn in 7 sheets the cost of the village map will be 7×2 or 14 annas and not 12 annas. In the case of Town maps, it may be stated, that 1. for convenience of survey, each ward has been divided into blocks, the area of each block being about 10 acres in crowded localities; 2. each block contains two or more properties; 3. the map of each block is printed in one or more sheets; 4. the maps are not coloured; 5. the price of each sheet is 4 annas. For illustrations as index plans, etc., the above available maps will be used shewing thereon the proposals in red. Details of proposals cannot be shewn in plans drawn to small scale. The following table shews at a glance the smallest dimension that can be shewn in the available survey maps :—

Scale of maps, 1 inch equals.	Smallest dimension of detail that can be shewn. Feet.
8 miles	704
6 miles	528
4 miles	352
2 miles	176
1 mile	88
1320 feet	22
660 feet	11
528 feet	8·8
330 feet	5·5
264 feet	4·4
132 feet	2·2
66 feet	

In cases where an existing map is drawn to a small scale and unsuitable for shewing thereon all details you desire to shew, then you may enlarge the drawing or you may survey the site with compass and chain or with chain only and plot the area to any scale you require. It may be that maps of the particular locality required by you are not available. In such cases, you will have to survey and prepare the required survey plans.

Scale For Drawings.

Having determined the longest and smallest dimensions required to be shown and as the size of plans in the P.W.D. is usually 38 inches × 25 inches within border lines, scales to which the plans should be drawn can be obtained from the following table :—

Scale.	Smallest dimension of detail that can be shewn.	Greatest length of detail that can be shewn in feet for a length of 36 inches.	Greatest breadth of detail that can be shewn in feet for a length of 23 ins.
1	2	3	4
1 inch = 1 inch	1/60 inch	3	1·9
1 inch = 2 inches	1/30 inch	6	3·8
1 inch = 3 inches	1/20 inch	9	5·7
1 inch = 4 inches	1/15 inch	12	7·7
1 inch = 6 inches	1/10 inch	18	11·5
1 inch = 8 inches	2/15 inch	24	15·3
1 inch = 10 inches	1/6 inch	30	19·16
1 inch = 12 inches	1/5 inch	36	23
1 inch = 2 feet	5/6 inch	72	46
1 inch = 3 feet	3/5 inch	108	69
1 inch = 4 feet	4/5 inch	144	92
1 inch = 5 feet	1 inch	180	115
1 inch = 6 feet	1⅕ inch	216	138
1 inch = 8 feet	1⅗ inch	288	184

Scale.	Smallest dimension of detail that can be shewn.	Greatest length of detail that can be shewn in feet for a length of 36 inches.	Greatest breadth of detail that can be shewn in feet for a length of 23 ins.
1 inch = 10 feet	2 inches	360	230
1 inch = 12 feet	2⅖ inches	432	276
1 inch = 16 feet	3⅕ inches	576	368
1 inch = 20 feet	4 inches	720	460
1 inch = 30 feet	6 inches	1080	690
1 inch = 33 feet	6⅗ inches	1188	759
1 inch = 40 feet	8 inches	1440	920
1 inch = 50 feet	10 inches	1800	1150
1 inch = 60 feet	1 foot	2160	1380
1 inch = 66 feet	1·1 feet	2376	1518
1 inch = 100 feet	1·66 feet	3600	2300
1 inch = 132 feet	2·20 feet	4752	3036
1 inch = 200 feet	3·33 feet	7200	4600
1 inch = 264 feet	4·40 feet	9504	6072
1 inch = 300 feet	5 feet	10800	6900
1 inch = 330 feet	5·5 feet	11880	7590
1 inch = 528 feet	8·8 feet	19008	12144
1/10	1/6 inch	30	19·2
1/25	1/12 inch	75	47·9
1/50	5/6 inch	150	95·8
1/75	1¼ inches	225	143·7
1/100	1⅔ inches	300	191·6
1/200	3⅓ inches	600	383·3
1/300	5 inches	900	575
1/400	6⅔ inches	1200	766·7
1/500	8⅓ inches	1500	958·3
1/600	10 inches	1800	1150
1/700	11⅔ inches	2100	1341·6
1/800	13⅓ inches	2400	1533·3
1/900	15 inches	2700	1725
1/1000	16·67 inches	3000	1916·6

When the size of a drawing is not limited by any given dimensions and in a case where the least dimension to be shewn is not found in column 2 of above table, the scale of the drawing should be that of the next smaller figure of col. 2 to that required. For instance, where the least dimension to be shewn is 5 inches and as this figure is not available in col. 2 the next lower figure to 5" in col. 2 is 4" and the scale corresponding to the least dimension of 4" is 1 inch equals 20 feet and this should be the scale of the drawing. In col. 1, are given the usual scales for drawings. Odd scales differing from those in col. 1 are inconvenient and not recommended in practice.

Sections.

We shall for the present understand that level sections are graphic representations showing 1. the lie of any locality with reference to a given datum line; 2. the proposals affecting the existing lie of a locality by constructing tanks, etc., 3. the levels of water supply pipe lines and drainage. From a perusal of plate 196 you will observe that two different scales are adopted ~~for the drawing. As the~~

least dimensions require to be shewn horizontally and vertically usually differ the scales are different. The scales to which these sections should be drawn are fixed with reference to table on page 18. Sometimes, both horizontal and vertical scales are same and then they are termed 'Natural scales,' see plate 164.

Plans Of Buildings.

As regards plans of buildings, I will refer you to the following plates:—Plates 6 to 10 are plans of buildings. In the case of drawings of buildings, the least dimensions usually required to be shewn vary from 4/5th of an inch to 2 inches and the scales for buildings are generally:—1 inch equals 4 feet; 1 inch equals 5 feet; 1 inch equals 6 feet; 1 inch equals 8 feet; 1 inch equals 10 feet; 1/50; 1/75; 1/100: (*Vide* table on page 18). The plan of a building is a delineation of a section cut along an imaginary horizontal plane and they are designated, Plan at ground floor; Plan at basement; Plan of first floor; and Plan of second floor. The sections are delineations, along imaginary vertical planes. The illustrations, plates 6 to 10, are selected and arranged carefully to enable you to understand them easily and also for the purpose of shewing the correct positions in building drawings for plans, sections, and elevation. As a rule in building drawing, the word 'Plan' is used for the horizontal sectional view of the building at basement level. This delineation of a building called 'Plan' is given with the purpose of shewing 1, the thickness of walls, 2, the size (except height) and shape of rooms, 3, the positions of doorways, windows, staircases, etc. When buildings are two or three storied, then plans at levels of the different floors should be given. One or more vertical sections are given for the purpose of shewing 1. the height of the rooms, 2. the depths of the floors, 3. the breadths and widths of the foundations, and 4. dimensions of doors, windows, and ventilators. On an inspection of plates 6 to 10 it will be seen that the above dimensions cannot possibly be shewn on the horizontal sections of the buildings termed 'plans.' An elevation is given to enable the view of a building to be undertstood. Usually this view is given as you view the front of a building; sometimes, end and rear elevations also are given. Before I conclude this portion of my lecture on building drawing I should take the opportunity of drawing your attention to a few important points. They are:—1. Every dimension required for estimating should be entered in figures in the drawing and on no account should any dimension be omitted which necessitates the estimator or the workman to obtain any required measurement by the use of the scale or the foot rule. It should be distinctly understood that the scale entered on a drawing is solely for the object of checking the drawing and not for obtaining any dimensions. 2. Over-all dimensions should in *every* case be given so that they may be stated without the use of the scales and without having to add a number of smaller dimensions.

ESTIMATING: MENSURATION OF SIMPLE SURFACES AND SOLIDS; THE MEASUREMENT OF AREAS AND VOLUMES INCLUDING THE CALCULATION OF SMALL QUANTITIES OF EARTHWORK, BRICK-WORK, MASONRY, ETC.; ESTIMATING AND DRAWING OUT DETAIL SPECIFICATION FOR MINOR AND TEMPORARY WORKS AND CALCULATION OF GRADIENTS.

Estimates.

An estimate is the written opinion of the intrinsic (money) worth, extent and quantities of the different kinds of work and materials proposed for any Engineering work. I use the expression 'opinion' in the definition of the word 'Estimate' as an estimate primarily implies an exercise of judgment in determining the amount, the suitability of the different kinds of work and materials and the magnitude and importance of any proposed Engineering work. The duty of drawing up an estimate is an important preliminary for the carrying out of any Engineering work and should be performed with considerable care and tact. As an estimate is a forecast of the probable amount required for the carrying out of a work, there is the possibility of the work being over-estimated or under-estimated. If a work is over-estimated then there is the result of the work never being done on the ground of the cost being excessive and beyond possible resources. On the other hand if it is under-estimated, the consequences are more serious as the excess funds required for the completion of a work if it was in progress may be found impossible to raise and the subordinate responsible for the estimate, if he is in service of Government or a Local Body, is severely dealt with. Every endeavour should be made to draw up your estimates for Engineering works so that your forecast is a very close approximation to the actual expenditure likely to be incurred in the construction of the work. The estimate will consist of (*a*) a report, (*b*) a specification, (*c*) a detailed statement of measurements and quantities, and (*d*) an abstract shewing the total estimated cost of each item and the grand total cost of all the items. The first requirement for preparing an estimate is a set of proper plans. The next requirement is a specification which is usually drawn up by Engineers or Assistant Engineers. When proper plans and specifications are available then the detailed estimate of measurements and quantities can be prepared. From the detailed estimate, the abstract estimate should then be drawn up. With the informations available in the above four documents a report should be drawn up which is usually done by Engineers and Assistant Engineers. In the work of preparation of an estimate the most important duty devolving on the junior subordinates of an Engineering Department is the drawing up of the detailed estimate of measurements and quantities to agree with the plans and the specifications furnished to the subordinate for the purpose of preparing a detailed estimate. In order to be able to do this, the subordinate should possess a knowledge of the ordinary rules of mensuration. In this view, the following essential rules of mensuration are here given.

Mensuration Of Surfaces.

(1) Area of a triangle = Base × $\frac{1}{2}$ perpendicular.

(2) Area of a triangle whose sides are a, b and c and half their sum is $s = \sqrt{s(s-a)(s-b)(s-c)}$

(3) Area of a square, rectangle, rhombus, or rhomboid, the opposite sides of which are parallel = Base × perpendicular.

(4) Area of a trapezoid, two sides only being parallel = Mean length × perpendicular.

(5) Area of a trapezium or any irregular figure = Areas of triangles into which the figure may be divided.

(6) Area of a circle = ·7854 × diameter^2.

(7) Circumference of a circle = 3·1416 × diameter.

(8) Area of a circular sector = Length of arc × $\frac{1}{2}$ Radius; or number of degrees in arc × area of the circle divided by 360.

(9) The area of a segment = Area of a sector — $\frac{1}{2}$ chord × (radius—Versin): or diameter^2 × x (see table.) $\frac{V}{D}$ = The versed sine divided by the diameter of the circle of which the segment is a part.

$\frac{V}{D}$	X	$\frac{V}{D}$	X	$\frac{V}{D}$	X	$\frac{V}{D}$	X	$\frac{V}{D}$	X
·01	·001329	·11	·047006	·21	·119898	·31	·207376	·41	·303187
02	003749	·12	·053385	·22	·128114	·32	·216666	·42	·313042
·03	·006866	·13	·059999	·23	·136465	·33	·226034	·43	322928
·04	·010538	·14	·066833	·24	·144945	·34	·235473	·44	·332843
05	·014681	·15	·073875	·25	·153546	·35	·244980	·45	·342783
·06	·019239	·16	·081112	·26	·162263	·36	·254551	·46	·352742
·07	·024168	·17	·088536	·27	·171090	·37	·264179	·47	·362717
·08	·029435	·18	·096135	·28	·180020	·38	·273861	·48	·372704
·09	·035012	·19	·103900	·29	·189048	·39	·283593	·49	·382700
·10	·040875	·20	·111824	·30	·198168	·40	·293370	·50	·392699

(10) Area of parabola = Base × 2/3 height.

(11) Frustum of a parabola =

$\frac{2}{3} \cdots \text{base}^3 - \text{top}^3$

(12) Surface of cylinder = Area of both ends + length × circumference.

(13) Surface of cone = Area of base + circumference of base × $\frac{1}{2}$ slant height.

(14) Surface of sphere = Diameter^2 × 3·14159.

(15) Surface of frustum = Sum of girth at both ends × $\frac{1}{2}$ slant height + area of both ends.

(16) Area of irregular figure = (Mean of extreme ordinates + sum of intermediate ordinates at equal distances apart) × length of figure divided by (number of ordinates—1).

Mensuration Of Solids.

(1) Solidity of cubes, parallelopipedons, and prisms = Area of base × perpendicular height.

(2) Solidity of cylinder = Area of one end × length.

(3) Solidity of sphere = Diameter^3 × ·5236.

(4) Solidity of segment of sphere = ·5236H (H^2+3R^2) where H = height of segment, and R = radius of the base of the segment.

(5) Solidity of cone or pyramid = Area of base × 1/3 perpendicular height.

(6) Solidity of frustum = 1/3 H ($A+a+\sqrt{A+a}$), where A and a = areas of the ends and H = perpendicular height.

(7) Solidity of frustum of cone = ·2618 H ($D^2+d^2+D.d.$), where D and d = the diameters of each end and H = perpendicular height.

(8) Solidity of wedge = Area of base × $\frac{1}{2}$ perpendicular height.

(9) Solidity of frustum of wedge = $\frac{1}{2}$ H (A + a) where A and a = area at each end, H = perpendicular height.

(10) Capacity of casks of any form in imp. gallons = ·00003147 L ($39\ M^2+25\ D^2+26\ M.D.$)

Where M = middle or bung diameter
D = diameter at end and
L = length of cask.

(11) Solidity of timber logs = ($\frac{1}{4}$ Middle girth)^2 × length.

If the log is very irregular or tapers much divide it into several lengths and measure each separately.

Properties Of The Circle.

Diameter	... ×	3·14159	=	circumference.
Diameter	... ×	·886226	=	side of an equal square.
Diameter	... ×	·7071	=	side of an inscribed square.
Diameter^2	... ×	·7854	=	area of circle.
Radius	... ×	6·28318	=	circumference.
Circumference	×	·31831	=	diameter.
Circumference			=	3·5449 $\sqrt{\text{area of circle}}$.
Diameter			=	1·1283 $\sqrt{\text{area of circle}}$.
Length of arc			=	number of degrees × ·017453 radius.

Specification Report For Scavengers' Huts: Plates 7 and 8.

In plates 7 and 8 is illustrated the Type Design No. 166 for Scavenger's Huts issued with Proceedings of the Madras Sanitary Board No. 154-S, dated 25-2-1915. The specification report which accompanied this design was as follows :—Foundations :—A depth of 1′ 6″ is provided in the estimate, the lower 6″ being concrete of broken brick in lime mortar and the upper 1′ 0″ being of country brick in lime mortar. Basement :—Country brick in lime mortar 1 foot high. Walling :—All walls will be of brick in clay except 1 foot on top of walls and sides of doors and windows which will be of brick in lime mortar, the thickness of walls being as shown upon the drawings. Stone work :—Bases of verandah posts will be of cut stone or Cuddapah slabs. Wood work :—All wood work will be of well seasoned country wood. Doors and windows :—All doors and windows will be of country wood. Roofing :—Roofing over rooms and verandahs will be of Mangalore tiles over teak reepers. Flooring :—The floors of all rooms and verandahs will be filled in with earth well rammed and plastered with mud and cow dung. Finishing :—The interior and exterior of walls will be pointed with lime mortar rough and whitewashed. All wood work will be coated with tar two coats. All works will be done in accordance with the standard specification of the Public Works Department. Cost :—The cost of these huts varies from Rs. 670 to Rs. 1,005 according to locality.

Detailed Estimate Of Quantities For Scavengers' Huts: Plates 7 and 8.

Detail of work.	Number.	Measurements in ft. Length.	Breadth.	Depth.	Area or contents.	Total quantity of each description of work.
		FT. IN.	FT. IN.	FT. IN.		
TWO SCAVENGER'S HUTS:						
Excavation for foundations.						
Main wall, all round ...	1	70 9	2 0	1 6	212	
Cross wall ...	1	7 1½	2 0	1 6	21	
Verandah retaining wall ...	1	28 1½	1 6	1 6	63	
Cross and end walls of verandah.	3	2 5¼	1 6	1 6	16	
Walls enclosing open yard ...	1	42 6	1 6	1 6	96	
Extra for one set of pilasters ...	2	2 11¼	0 5¼	1 6	4	
Cross wall in do. ...	1	7 2¼	1 6	1 6	16	
Walls of kitchen ...	2	7 9	1 6	1 6	35	
Steps ...	2	3 6	0 6¾	0 6	2	
Total, c. ft. ...	...	...	...	...	...	465

Detail of work.	Number.	Measurements in ft. Length.	Breadth.	Depth.	Area or contents.	Total quantity of each description of work.
Earth filling in basement and forming floor with a coat of mud and cow dung.						
Rooms ...	2	12 0	8 0	...	192	
Verandahs ...	2	12 6¾	3 3	...	82	
Kitchen ...	2	3 3	4 6	...	29	
Total, s. ft. ...	...	...	...	...	...	303
Concrete broken brick in lime mortar.						
Main wall all round ...	1	70 9	2 0	0 6	71	
Cross wall ...	1	7 1½	2 0	0 6	7	
Verandah retaining wall ...	1	28 1½	1 6	0 6	21	
Cross and end walls of verandah...	3	2 5¼	1 6	0 6	5	
Wall enclosing open yards ...	1	42 6	1 6	0 6	32	
Extra for one set of pilasters ...	2	2 11¼	0 5¼	0 6	1	
Cross wall do ...	1	7 2¼	1 6	0 6	5	

Detail of work.	Number.	Measurements in ft. Length.	Breadth.	Depth.	Area or contents	Total quantity of each description of work.
Walls of kitchen ...	2	7 9	1 6	0 6	12	
Steps ...	2	3 6	1 0	0 6	4	
Total, c. ft. ...	...	...	...	...	...	158
Country brick in lime mortar (foundations and basement.)						
Main walls, all round ...	1	70 9	1 1½	2 0	159	
Cross wall ...	1	8 0	1 1½	2 0	18	
Verandah retaining wall ...	1	27 4½	0 9	1 9	36	
Cross and end walls of verandahs.	3	3 3	0 9	1 10½	14	
Wall enclosing open yard ...	1	43 4½	0 9	1 6	49	
Extra for set of pilasters ...	2	2 1½	0 4½	1 6	2	
Cross wall ...	1	8 0	0 9	1 6	9	
Wall of kitchen ...	2	8 6	0 9	1 6	19	
Steps ...	2	3 0	0 9	0 6	2	
Total, c. ft. ...	...	...	...	...	...	308

Detail of work.	Number.	Measurements in ft. Length.	Breadth.	Depth.	Area or contents.	Total quantity of each description of work.
Country brick in mud (superstructure).						
Main walls, front and rear ...	2	27 4½	1 1½	8 4½	516	
Cross and end walls ...	3	8 0	1 1½	8 9	236	
Gables ...	3	8 0	1 1½	1 4	36	
Verandah cross end walls including gables ...	3	4 0	0 9	6 8	60	
Wall enclosing open yard ...	1	43 4½	0 9	6 0	195	
Extra for one set of pilasters ...	2	2 1½	0 4½	6 0	10	
Cross wall ...	1	8 0	0 9	6 0	36	
Side wall of kitchen ...	2	4 0	0 9	5 0	30	
Front wall of kitchen with gables	2	4 6	0 9	6 9	46	
Wall over cross wall ...	1	4 0	0 9	2 6	8	
Gable over rear wall ...	1	3 9	0 9	2 6	7	
Total ...	...	...	...	...	1,180	

Detail of work.	Number.	Measurements in feet. Length.	Breadth.	Depth.	Area or contents.	Total quantity of each description of work.
Deduct for—		FT. IN.	FT. IN.	FT. IN.		
Doors in main walls ...	4	3 0	1 1½	6 0	81	
Doors in yard walls ...	2	2 3	0 9	6 0	20	
Windows ...	2	3 0	1 1½	4 0	27	
Kitchen openings ...	2	2 6	0 9	5 0	19	
Brick in lime mortar, superstructure, as detailed below.	...	...	...	...	251	
Archwork, brick in lime mortar, as detailed below.	...	...	...	...	32	
Total deductions, c. ft. ...	...	...	...	...	430	
Net total, c. ft. ...	...	...	...	...	...	750

Detail of work.	Number.	Measurements in ft. Length.	Breadth.	Depth.	Area or contents.	Total quantity of each description of work.
Country brick in lime mortar, (superstructure).		FT. IN.	FT. IN.	FT. IN.		
One foot on top of walls around doors and windows ...	...	...	...	...	...	
Main walls, front and rear ...	2	27 4½	1 1½	1 0	62	
Cross and end walls ...	3	8 0	1 1½	1 0	27	
Verandah cross and end walls ...	3	4 0	0 9	0 9	7	
Ends of do. ...	3	5 0	0 9	0 9	8	
Wall enclosing open yard ...	1	34 6	0 9	0 9	19	
Pilasters ...	4	1 1½	1 1½	5 6	28	
Cross wall ...	1	8 0	0 9	0 9	5	
Side wall of kitchen ...	2	8 6	0 9	0 9	10	
Sides of doors ...	4	12 0	1 1½	1 0	54	
Sides and sills of windows ...	2	11 0	1 1½	1 0	25	
Sides of kitchen opening ...	2	5 0	0 9	0 9	6	
Total, c. ft. ...	...	...	...	..	...	251

Detail of work.	Number.	Measurements in ft. Length.	Breadth.	Depth.	Area or contents.	Total quantity of each description of work.
Archwork, country brick in lime mortar.						
Over doors ...	4	3 9	1 1½	1 1½	19	
Over windows ...	2	3 9	1 1½	1 1½	9	
Over kitchen opening ...	2	3 1½	0 9	0 9	4	
Total, c. ft. ...	...	...	...	...	...	32
Cut stone or Cuddapah slabs.						
Under verandah pillars ...	2	...	...	...	2	
Total No. ...	...	...	...	...	...	2
Country wood wrought and put up.						
Main room rafters, long, 1' 6" centres ...	18	8 0	0 2	0 3½	7·00	
Do. small ...	18	6 3	0 2	0 3½	5·47	

Detail of work.	Number.	Measurements in ft. Length.	Breadth.	Depth.	Area or contents.	Total quantity of each description of work.
Verandah rafters ...	18	7 6	0 2	0 3½	6·56	
Collar pieces ...	18	7 3	0 2	0 3½	6·34	
Rafters in kitchen ...	2×4	7 0	0 2	0 3½	2·72	
Verandah bressummer ...	1	28 0	0 4	0 5	3·88	
Wall plate ...	2	27 0	0 4	0 3	4·50	
Ridge piece and wall plate for kitchen ...	3	4 0	0 3	0 3	0·75	
Caps for posts ...	2	1 0	0 4	0 6	0·33	
Total, c. ft. ...	...	...	...	...	...	37·55
Country wood pillars 5" dr. including painting, etc., complete.						
In verandah ...	2	...	...	...	2	
Total No. ...	...	...	...	...	...	2

Detail of work.	Number.	Length.	Breadth.	Depth.	Area or contents.	Total quantity of each description of work.
Country wood ledged doors with frames and fittings, etc., complete.						
Doors, large ...	4	3 0	...	6 0	72	
Do., small ...	2	2 3	...	6 0	27	
Total, s. ft. ...	...	...	...	...	...	99
Country wood batten windows with iron bars including frames and fittings, complete.						
Windows ...	2	3 0	4 0	...	24	
Total, s. ft. ...	...	...	...	...	...	24

Detail of work.	Number.	Length.	Breadth.	Depth.	Area or contents.	Total quantity of each description of work.
Roofing with Mangalore tiles including teak reepers, etc., complete.						
Over rooms and verandahs ...	1	28 9	20 0	...	575	
Over kitchen ...	1	14 0	5 0	...	70	
Total, s. ft. ...	...	...	...	...	...	645
Pointing with lime mortar including white washing.						
Rooms, wall all round ...	2	40 0	...	8 9	700	
Gable walls ...	4	8 0	...	1 4	43	
Verandah walls ...	2×2	12 6¾	...	8 0	402	
Cross and end walls of verandah...	4	4 0	...	6 9	108	
Kitchen all round ...	2	15 6	...	5 3	163	
Partition over cross wall ...	2	3 3	...	3 0	20	

Detail of work.	Number.	Length.	Breadth.	Depth.	Area or contents.	Total quantity of each description of work.
Gables ...	4	4 6	...	1 9	32	
Basement, front ...	1	27 4½	...	0 9	21	
Do. rear ...	1	25 1½	...	1 0	25	
Do. sides ...	2	14 3	...	1 0	29	
Exterior of verandah walls ...	2	4 0	...	6 9	54	
Ends of verandah walls ...	3	0 9	...	6 9	15	
Exterior of main walls ...	2	10 3	...	9 9	200	
Cross wall of yard, both sides ...	1	4 0	...	12 9	51	
Interior of do. ...	2	15 9	...	6 0	189	
Exterior of do. ...	1	94 10½	...	6 0	569	
Kitchen walls ...	2	8 10½	...	5 6	98	
Gables of do. ...	2	11 3 / 2	...	3 9	42	
Sides and soffits of doors, large ...	4	15 0	...	1 1½	68	
Sides, soffits and sills of windows	2	14 0	...	1 1½	32	

Detail of work.	Number.	Length.	Breadth.	Depth.	Area or contents.	Total quantity of each description of work.
Sides of doors, small ...	2	12 0	...	1 1½	27	
Sides and soffits of openings in kitchen ...	2	12 6	...	0 9	19	
Total, s. ft. ...	...	...	...	...	2,907	
Deduct for—						
Doors, large ...	4×2	3 0	...	6 0	144	
Do. small ...	2×2	2 3	...	6 0	54	
Windows ...	2×2	3 0	...	4 0	48	
Openings in kitchen ...	2×2	2 6	...	5 0	50	
Total deductions ...	...	...	...	...	296	
Net total s. ft. ...	...	...	...	...	...	2,611

Detail of work.	Number.	Measurements in ft. Length.	Breadth.	Depth.	Area or contents.	Total quantity of each description of work.
Tarring, two coats.						
Main room rafters, long ...	18	8 0	...	0 9	108	
Do. small ...	18	6 3	...	0 9	84	
Verandah rafters ...	18	7 6	...	0 9	101	
Collar pieces ...	18	7 3	...	0 11	120	
Kitchen rafters ...	2×4	7 0	...	0 9	42	
Verandah bressummer ...	1	27 3	...	1 4	36	
Wall plate of rooms ...	2	27 0	...	1 2	63	
Ridge piece and wall plates of kitchen ...	3	4 0	...	1 0	12	
Caps of posts ...	2×2	1 0	...	0 6	2	
			Coefft			
Doors, large ...	4	3 0	2¼	6 0	162	
Doors, small ...	2	2 3	„ 2¼	6 0	61	
Windows ...	2	3 0	„ 2¾	4 0	66	
Total, s. ft. ...	...	...	...	...	...	857
Gravelling, 6" thick, including watering and ramming.						
Open yards ...	2	12 6¾	4 0	...	101	
Do. ...	2	7 8¾	4 0	...	59	
Total, s. ft. ...	...	...	...	...	...	160
Forming fire places with pot ovens and providing chimney.						
No. ...	...	...	...	...	...	2
Providing sink (washing platform).	...	...	...	...	...	L. S.
Providing brick cornice outside gables.	...	...	...	...	...	L. S.

I have given the detailed estimate for the design of scavengers' huts to serve as a specimen as to how detailed estimates are prepared. It is not proposed to add detailed estimates in the other cases as the size of this book will be increased inordinately and also with the view that you should prepare the detailed estimates in other cases either as exercises or when required.

Abstract Estimate.

I give below the abstract for the detailed estimate for scavengers' huts.

Quantity.	Description of work.	Rate.	Per.	amount.	Total.
465 c. ft.	Earthwork excavation for foundations	...	1,000 c. ft.	...	...
303 s. ft.	Earth filling in basement and forming floor with a coat of mud and cow dung ...	...	100 s. ft.	...	...
158 c. ft.	Concrete, broken brick in lime mortar	...	100 c. ft.	...	...
308 „	Country brick in lime mortar, in foundations and basement ...	...	„	...	...
750 „	Country brick in mud, superstructure	...	„	...	...
251 „	Country brick in lime mortar, superstructure	...	„	...	...
32 „	Archwork, country brick in lime mortar	...	„	...	...
2 Nos.	Cut stone or Cuddapah slab under post	...	Each.	...	...
37·55 c. ft.	Country wood, wrought and put up		c. ft.	...	...
2 Nos.	Country wood, 5" diameter, posts including painting, etc., complete	...	Each.	...	...
99 s. ft.	Country wood ledged doors with frames and fittings, etc., complete	...	s. ft.	...	...
24 „	Country wood batten windows with iron bars including frames and fittings	...	„	...	...
645 „	Roofing with Mangalore tiles including teak reepers, etc., complete	...	100 s. ft.	...	...
2,611 „	Pointing with lime mortar including white washing ...	...	„	...	...
160 „	Gravelling, 6" thick, including watering and ramming ...	...	„	...	...
857 „	Tarring, two coats	...	„	...	...
2 Nos.	Forming fire place with pot ovens and providing chimneys ...	...	Each.	...	...
L. S.	Providing sink place ...	..	L. S.	...	...
L. S.	Providing brick cornice outside gables	...	L. S.	...	...
	Total, Rs. ...	...	...	...	...
...	Contingencies at 5 per cent. ...	...	...	...	...
...	Petty supervision at 2½ per cent..	...	...	...	...
	Total of estimate, Rs. ...	...	...	...	...

Rates And Data For Rates.

Rates for works and materials are different at different places. To facilitate the preparation of estimates, a schedule of current rates of each kind of work commonly executed is maintained in P. W. Divisions, in District Boards and Municipalities. The rates noted in the schedules are to be generally adopted in the preparation of all estimates. If, for any reason, say, owing to the remoteness of work, labour has to be brought from a distance, these rates are found insufficient, then an increased rate can be allowed, provided that clear and specific reasons are given for such an extra rate. On the other hand, if these rates are found too high, owing to the unusual facility of obtaining certain materials, a lower rate should be adopted with a note to that effect. The rates in the schedule are average rates. In all estimates, for easy reference item numbers should also be quoted. Data should invariably accompany all estimates. The data will comprise the schedule rate and the actual cost of conveying materials to the worksite.

Cart Loads.

Laterite, broken granite, or rough stone ...	10 c. ft.
Granite stone, or asphalt ...	7 c. ft.
Broken laterite, sand, gravel, cement, or surkhi	$12\frac{1}{2}$ cub. ft.
Lime, coke, tar, pitch, or wood .	20 cub. ft.
Bricks ($8\frac{1}{2}'' \times 4\frac{1}{4}'' \times 2''$) arch bricks ($9'' \times 4\frac{1}{2}'' \times 1\frac{1}{2}''$) ...	400 No.
Terrace bricks ($5'' \times 3'' \times 1''$) or thick flat tiles ($5\frac{1}{2}'' \times 3\frac{1}{2}'' \times \frac{3}{4}''$) ...	1100 No.
Thin flat tiles ($5\frac{1}{2}'' \times 5'' \times \frac{1}{2}''$) ...	1500 No.
Pan tiles ($8'' \times 5'' \times \frac{1}{2}''$) ...	1000 No.
12" Flooring tiles or bricks ($11\frac{1}{2}'' \times 11\frac{1}{2}'' \times 2''$) ...	60 No.
10" Do. ($9\frac{1}{2}'' \times 9\frac{1}{2}'' \times 1\frac{3}{4}''$) ...	110 No.
8" Do. ($7\frac{1}{2}'' \times 7\frac{1}{2}'' \times 1\frac{5}{8}''$) ...	220 No.
6" Do. ($5\frac{1}{2}'' \times 5\frac{1}{2}'' \times 1\frac{1}{2}''$) ...	400 No.
Any load ...	1000 lbs.

Gradients.

A gradient is the degree of slope or rate of inclination of any surface, as, for example, a road, railway, drain or sewer. When it is said that the gradient of a sewer is 1 in 100, this means that the sewer in 100 feet, measured horizontally, falls 1 foot, measured perpendicularly. The rule for calculating gradients is to divide the horizontal length by the difference of the heights at extremities above the datum line, and the quotient is the horizontal measurement to a rise or fall of one foot. For example, the level of invert of a sewer 785 feet long at commencement is 269·20 and at end 261·35, thus giving a slope of 269·20—261·35 = 7·85 feet. The gradient is $\frac{785}{7.85}$ or 1 in 100.

BUILDINGS: KNOWLEDGE OF THE VARIOUS BUILDING MATERIALS, SUCH AS BRICK, STONE, LIME, SURKHI, ASPHALT, PAINTS, ETC., THEIR QUALITY AND THE POSSIBLE INFLUENCE OF ATMOSPHERE ON THEM: THEIR SUITABILITY IN VARIOUS PARTS OF A BUILDING: TO DISTINGUISH BETWEEN GOOD AND BAD BRICK, TIMBER, LIME, CEMENT, ETC., THE NECESSITY FOR FOUNDATIONS, THEIR PROPER DEPTH.

Building Materials.

The strength and durability of structures depend on two things, first, the use of good and suitable materials; and, secondly the application of such materials in a judicious and efficient manner. There is no doubt that the best sort of the several kinds of material can be selected by attentive observation and considerable experience. However, the following notes regarding the nature, production and uses of building materials will, it is hoped, be of some help to beginners and prevent them from falling into very serious errors in the choice of materials. The materials used may be classified as follows:—(I) Solid Materials:—Stone, Brick, Wood, Metals. (II) Cementing Materials:—Limes, Cements, Mortars, Mastics and Glue. (III) Protecting Materials:—Plasters and Paints.

Stones.

The chemical composition and physical properties of the different stones are outside the scope of the present lecture. They will not therefore be discussed here. The stones used in building works are generally divided into three classes, each distinguished by the earth which forms its principal constituent:—(1) the siliceous, (2) the argillaceous and (3) the calcareous, according as silica, clay, or carbonate of lime (calcium carbonate), forms the base or chief constituent. The principal varieties of the three classes of stones are as follow:—(1) Siliceous stones: Granite, Trap, and Sandstone (2) Argillaceous stones: Slate and Laterite (3) Calcareous stones: Limestone, Kankar and Gravel.

Granite.

The varieties of stone, *viz.*, syenite and gneiss are also called granite. Granite is the most durable building material. Good granite is hard, compact and non-porous, is of a hard and close texture and of uniform dark grey colour and cannot be easily crushed or broken. Decayed granite is mottled in appearance and colour and is easily broken and crushed. Such stone should always be rejected. The gneiss, commonly called granite, which is dark in colour and generally used in important works in the city of Madras is obtained from the quarries at Pallavaram. From the quarries at Sholingur, gneiss is procured and used in buildings in this city. Granite is found in several districts of this Presidency though not everywhere. The chief obstacle to the use of granite is its great cost for dressing the stone. Fine work is very expensive. It is therefore used only in important buildings and that only when it is obtainable in the immediate neighbourhood. It is however used in certain parts of ordinary buildings, *viz.*, (1) posts for verandahs, market sheds, (2) bed plates for distributing pressure, (3) flags for flooring and (4) slabs for covering drains, manholes, and valve pits etc. Granite, in its rough state is used in the foundations of buildings, in revetment for protection of tank bunds, for making concrete, and mile and furlong posts.

Trap.

Trap is a variety of siliceous stones. The best quality of trap is hard, of a bright colour breaking with a clean fracture and ringing when struck with a hammer, and is well suited for paving and metalling roads. Many stations in the G. I. P. Railway as well as several ancient and modern buildings in and around Bombay are constructed of this stone.

Sandstone.

Sandstone is the third principal variety of siliceous stones. All the stones belonging to this class—of which there is a great variety—are eminently suitable for building purposes, either as cut stone or rubble. The colours of sandstone are very various, white, yellow, grey, greenish grey, light brown, dark blue, and even black. In this Presidency it is found in South Arcot, Nellore, Cuddappah and Kurnool. The Y. M. C. A. building and the Victoria Technical Institute of this city are built of sandstone from Tada near Nellore.

Slate.

Slate is a variety of argillaceous or clayey stones and varies much in colour, the common varieties being dark blue, bluish black, purple grey and green. A good slate should not absorb water to any perceptible extent, and should give out a sharp metallic ring when struck with the knuckles. In this Presidency the slabs from Cuddapah rank first as regards durability, impermeability and cheapness as material for paving. The slabs at Kurnool are used for walls and flagging.

Laterite.

Laterite is a variety of argillaceous stones and is employed as a building stone in Malabar, Trichinopoly, Tanjore and South Arcot. It is very easy to work but care is required in selection of stone, as the inferior sorts decay rapidly when exposed to weather. Laterite being benefited by long exposure, should never be used when freshly quarried, especially from any depth. It should not be used when subject to any great pressure. Nodular laterite is used in this city as a road metal.

Limestones.

The durability of the stone depends much upon its texture. The best weathering limestones are dense, uniform, and homogeneous in structure and composition, with fine, even small grains, and of a crystalline texture. They are for the most part uniform in tint and easily wrought. The varieties of limestone in use are (1) Marble, (2) Compact Limestone, (3) Granular Limestone and (4) Magnesium Limestone or Dolomite. Marble is translucent and capable of a fine polish. Some marbles retain their polish when under cover, but lose it when exposed to weather. Some marbles are very handsome. Marble is one of the most durable of stones. Its scarcity and value prevent its being used except for columns, pilasters, etc., in ornamental buildings. The less handsome varieties are, however, used for ordinary building in the neighbourhood of the quarries. Marble can generally be quarried in large blocks. India possesses some fine specimens of large buildings constructed wholly of marble, such as the Mootee Musjid and Taj Mahal at Agra. Compact limestones are very useful as building stones where their dull colour and the difficulty of working them are not objections. They are used for paving set and road metal under a light traffic. The most frequent colours of compact limestones are white, greyish blue and whitish brown. Limestone is used for building purposes at Cuddappah, Kurnool and Guntur. Granular limestones are always more or less porous and the less porous, the more durable. They are found of various colours, especially white, light yellow, light brown, or cream colour. Their durability varies extremely. Some durable varieties are used in buildings on account of their pleasing colour and texture. Portland Stone and Bathstone are examples of durable granular limestones. Magnesium Limestone or Dolomite is found in various conditions from the compact to the granular. Its durability to a considerable extent depends on its texture. When that is compact, it is nearly as lasting as marble which it resembles in appearance; when porous, it is very perishable.

Kankar And Gravel.

Kankar and gravel are other varieties of calcareous stones. The principal value of kankar is as a source of lime. Kankar nodules are generally 3 or 4 inches in diameter. Kankar is sometimes found in large masses in the beds of streams. Gravel pebbles are found in alluvial tracts of country and in the beds of rivers. The pebbles vary in size from 3 or 4 inches in diameter to minute grains. Large water-worn pebbles are called shingles. Gravel is used for wearing coats of roads and also for making concrete.

Specifying Stone.

All stone should be sound, free from decay, flaws, cracks, veins or cavities, and, so far as possible of uniform colour and texture. Blocks required for dimensioned stuff must be quarried true and square, and as near the dimensions given as possible. Rubble stones should be as square and evenly bedded as possible, and in as large pieces as the quarry will permit consistently with facility of being handled. No irregularly shaped or unevenly-bedded pieces should be permitted and no stone should contain less than $\frac{1}{3}$ of a cubic foot. In quarrying stone for building purposes there should be as little blasting as possible as it shakes the stone besides causing considerable waste. Care should be taken to cut the blocks so that they can be placed in the work for which they are intended with their natural beds at right angles to the pressure that will come upon them.

Strength Of Stones.

Our knowledge of the strength of stones is very limited, although they are the most generally useful of building materials. Generally speaking, amongst stones of the same kind, that which has the greatest weight is almost invariably the strongest. Stones in ordinary building or engineering works are generally under compression, occasionally subject to cross strain, but never to direct tension. The compression that comes upon a stone in an ordinary building is never sufficient

to cause any danger of crushing, as will be seen from the following table of ultimate strength to resist crushing taken from Captain Marryat's Specification.

Ultimate Strength Of Different Stones To Resist Crushing.

	Lbs. per sq. inch.
Basalt, Bombay — Dark blue	10 200
Basalt, Bombay — Light blue	4,800
Do. Kurla, yellow	9 840
Ahemnuggur	5.000
Porbandar	2.120
Dhrangadhra	5.611
Granite	26,000 to 36,000
Limestone (marble)	5,500
Sandstone, strong	5.500

Rubble masonry, about four-tenths of cut-stone.

It is generally laid down that the compression to which a stone may be subjected in a structure should not exceed 1/10 of the crushing weight. It is possible in some forms of arches, in retaining walls, and in other structures that a considerable pressure may be concentrated upon certain points which are liable to be crushed.

Durability Of Stones.

The power of resisting atmospheric and other external agencies is the first essential in stones for almost any purpose. The durability of a stone depends upon its chemical composition, mechanical structure, and its place in a building. The chemical composition of the stone should be such that it will resist the action of the atmosphere and of the deleterious substances which, especially in large cities, the atmosphere contains. These destroying substances are taken by the moisture in the air, or by the rain, and thus conveyed into the pores of the stone. The sulphur acids, hydrochloric acid, and traces of nitric acid in the air of towns, and carbonic acid which exists in the pure atmosphere of the country, ultimately decompose any stone of which either carbonate of lime or carbonate of magnesia forms a considerable part. A stone which will weather well in the pure air of the country may be rapidly destroyed in the smoky atmosphere of large towns. The influence of rain, wind, and frost have also to be considered. Stones are less attacked in dry weather than during rain; the destructive acids cannot penetrate so deeply, and the frost has no influence when the stone is dry. The number of days on which there is rain in any district has therefore a great influence on the durability of stone used in that district. A gentle breeze dries out the moisture, and thus favours the lasting qualities of stone; whereas, high winds on the other hand, force the rain into pores of the stone, and thus cause a considerable depth to be subjected to the effect of acids and frost. The mechanical structure of a stone is of the greatest importance, for upon it depends greatly its power of resisting the action of the atmosphere. Stones which are crystalline in texture weather better than those that are non-crystalline. Chalk and marble, for example, or of the same chemical composition—both nearly pure carbonate of lime, yet the latter, especially when polished, will resist an ordinary atmosphere for a long time, while the former is rapidly disintegrated and destroyed. If the chemical composition and remaining qualities of two stones are the same, then the stone which has closer and finer grain of the two is likely to be more durable than the other. If the grains be easily decomposed and the cementing material lasting the stone will become porous and liable to destruction by frost. If the cementing material is destroyed the grains will fall to pieces. Stone should contain no soft patches or inequalities; unequal weathering leaves projections which catch the rain and hasten decay. The position of a stone in a building may very much influence its durability. A stone in that side of a building, which faces the prevailing rains, is of course, more liable to decay than it would be on the other side. In the same way any faces of stone that are sheltered altogether from the sun and breeze so that the moisture does not quickly dry out are liable to decay. This may be noticed especially in buildings constructed of an inferior stone and situated in a bad atmosphere.

Testing The Durability Of Stones.

The durability of stone is best ascertained by examining samples in buildings which have stood for a long period. If the stone has good weathering qualities, the faces of the blocks, even if very old, will exhibit no sign of decay, but on the contrary, the tool marks will be distinctly visible. When this cannot be done, the stone should be subjected to direct experiment. Speaking generally, when the texture is uniform and compact, the grains fine and the specific gravity great, the stone lik wear well; and when comparing stones of the same class, the less porous, most dense, and strongest will generally be the most durable.

Preservation Of Stones.

The decay of all natural building stone is the combined effect of various causes. The various contrivances which have been tried or proposed for the preservation of naturally porous stone, all consist in filling the pores of the stone at or near the exposed surface with some substance which will exclude air and moisture. s may be d ie pores of the stone with preparations containing dissolved organic matter. These preserve the stone for a time, but they are themselves

subject to decay, and, therefore, can give only a temporary protection. Or solutions of inorganic substances may be used which act either upon the constituents of the stone to which they are applied, or upon one another (when more than one is applied) so as to form insoluble compounds which fill the pores and harden the structure of the stone, at the same time, making it denser, more impervious, and better able to resist the acids and other injurious vapours that water in being absorbed would carry along with it. Drying oil, such as boiled linseed oil, has been used as a coating. It fills the pores and keeps out the air for a time, but it discolours the stone to which it is applied. It is moreover gradually destroyed by the oxygen of the air, so that it requires to be renewed from time to time. Paint: One of the most common methods of preserving the surface of stone is [illegible] aint fills the pores of the stone, but as in the case of drying oil, it destroys the crystalline appearance which constitutes the beauty of most stones and is itself destroyed by atmospheric influence. Bituminous matter, such as coal-tar, is very effective but unsightly from its colour. Paraffin is more lasting than oil, but is open to the same objection as regards discoloration of the stone. Paraffin dissolved in coal-tar naptha and applied warm is very effective. Soluble silica is the name given to a large class of preparations, which have been tried, especially of late, and which give promise of much better results than are likely to follow the use of organic substances. Before pplying any of the above preparations, the surface of the stone [illegible] oroughly clean and perfectly dry.

Artificial Stone.

The difficulty which exists in many places of obtaining durable stone at a moderate cost, and the desire to possess a material, which, while possessing all the qualities of natural stone, could, at the same time, be moulded like clay into any required form, have given rise, within the past few years, to a large number of processes, more or less practical, for the manufacture of artificial stone. Some processes have been successful in producing artificial stones, which compare favourably in all their properties with good natural stone. The expense, however, of artificial stone will, it is to be feared, be always a hindrance to its extensive use for ordinary blocks, but the facility with which it can be moulded to intricate forms, makes it very economical when it is required to take the place of carvings or other ornament in natural stone.

Bricks.

Bricks are made of tempered clay formed in a mould to the requisite size and shape, and dried in the sun. In this condition they may be used for building, and are called sun dried, or in Hindustani Cutcha bricks. For most permanent works, however, the bricks, are hardened by strong heat in a kiln, and when thus prepared are called Pucka. But on account of imperfections in the application and distribution of the heat in a kiln, it never happens that all the bricks put in are thoroughly fired to the required extent and no further. Some which have not received sufficient heat are only partially hardened, such are known as Grizzle or Place bricks; and from their generally yellowish tinge, have, in this country, received the name of Pila. Some, on the other hand, may have received too much heat, and, when this happens, they are found more or less vitrified, dark coloured, hard, and brittle. Such are also frequently distorted, and when this over-burning has proceeded to greater extent, they are found partially fused and run together into masses, not unfrequently of large size. These irregular lumps of over-burnt bricks are called Burrs or Jhama.

Characteristics Of Good Bricks.

In order to ensure good brickwork, the bricks must be regular in shape and uniform in size; with plane parallel surfaces and sharp right-angled edges. The amount of water absorbed by bricks is to a certain extent an indication of their quality and their strength. Very highly vitrified bricks should not absorb more than 1/15 of their weight of water; but the average brick used in building is often found to absorb as much as 1/12 to 1/6. A perfect burnt brick will remain any length of time under water uninjured, and this quality is so essential to hydraulic works that the absorbing power of bricks employed should be carefully tested before using them. An insufficiently burnt brick on the other hand, is incapable of withstanding continued exposure to the action of water; it softens and is liable to be crushed. In ordinary walling, it absorbs a large proportion of damp; and is very liable to be affected by the action of saltpetre or other salts (always present in the soil of most Indian towns), which, on crystallising, causes the bricks to crumble away. A good brick is generally of a clear and uniform colour, depending on the nature of the clay of which it is made, and partly also on the kind of fuel with which it has been burnt. Bricks of a deep red colour are generally good. They should be hard, and burnt so thoroughly that there is incipient vitrification all through each brick. This may be seen on examining a fractured surface. A test of hardness is that the finger nail should not be able to make any impression on the surface. A well-burnt brick should give out a clear ringing sound when struck. A dull sound indicates a soft or shaky brick. Strength: In practice, bricks are subject to compression and sometimes to transverse stress,

but seldom or never to tension. The compressive stress brought upon evenly-bedded bricks is generally less than they are able to bear. In some cases, however, as in arches and retaining walls, the stresses may be concentrated upon a small portion of the brick, or the same effect may be produced by the bed of the brick in wall being uneven. The strength of bricks, which varies very much, depends chiefly upon the nature of the clay of which they are made, and the extent to which the burning has been carried. Rankine, however, states that good bricks require at least 1,100 lbs. on the square inch to crush them, and that they will sometimes bear considerably more. A small pillar of brickwork made of bricks of good quality laid in cement should require from 800 to 1,000 lbs. on the square inch to crush it. Bricks in general begin to show signs of giving way by splintering and cracking under about one-half or two-thirds of their crushing load. The weaker qualities of bricks may be estimated as having from one-half to two-thirds of the strength stated above.

Specifying Bricks.

The brick should be whole, well burnt, free from cracks, flaws, stones or lumps of any kind; should be sound and hard to resist compression; and should be of regular size and shape to ensure uniformity in the thickness of the courses of brick-work. A brick thoroughly burnt and sound will give out a clear ringing sound when struck, and should be of a uniform (generally deep, red or copper) colour. All bricks which absorb more water than one-fifth of their own weight when dry should be rejected.

Varieties Of Bricks And Their Sizes.

Bricks are made of different sizes according to the custom of the country, their use and the mode of manufacture. For proper bonding, the length of a brick should equal twice its width plus a mortar joint (which is usually $\frac{1}{4}$ inch). The thickness of a brick varies from 1 inch to 3 inches and usually taken as $\frac{1}{3}$ of length minus one mortar joint. Madras Government bricks are $9\frac{3}{4}'' \times 4\frac{3}{4}'' \times 3''$. The less the dimensions of a brick the greater the quantity of mortar consumed in masonry and therefore also the cost. The greater the dimensions of a brick the more difficult and expensive it is to burn it as well as to handle it. The following are the usual sizes of bricks available :—

1. Government bricks ... $9\frac{3}{4}'' \times 4\frac{3}{4}'' \times 3''$
2. Stock bricks or Table moulded bricks ... $8\frac{3}{4}'' \times 4\frac{1}{2}'' \times 2\frac{1}{2}''$
3. Ground moulded bricks ... $9'' \times 4\frac{1}{2}'' \times 2''$
4. Ground moulded bricks ... $8\frac{3}{4}'' \times 4\frac{1}{2}'' \times 1\frac{1}{2}''$
5. Machine made bricks ... $9'' \times 4\frac{1}{2}'' \times 2\frac{3}{4}''$
6. Platform moulded bricks ... $9'' \times 4\frac{1}{2}'' \times 2\frac{1}{4}''$
7. Native bricks ... $9'' \times 4'' \times 1\frac{3}{4}''$ or $7'' \times 3\frac{1}{2}'' \times 1\frac{1}{2}''$ or $9'' \times 4'' \times 2''$

A brick weighing about 9 lbs. and measuring $9\frac{3}{4}'' \times 4\frac{3}{4}'' \times 3''$ may be taken for an economic size. Bricks may be classified according to their use as wall, well, arch, terrace, cornice, drain bricks etc. The wall bricks are the ordinary rectangular bricks described above. The well bricks are broader at one end than at the other. The arch bricks are thinner at one end than at the other. The cornice bricks are specially moulded where cornice cannot be made entirely of projections of ordinary brick and plaster. Drain bricks are made of special size and shape and includes both the cunettes as well as the bull's noses. There are a host of different varieties specially moulded and burnt for different purposes. In making moulds for manufacture of bricks for any purpose due allowance should be made for the necessary shrinkage during manufacture. Fire bricks are made from refractory clays, that is, clays which are capable of bearing a high temperature without becoming soft, being almost pure hydrated silicate of alumina. Coloured bricks are made either by mixing certain colouring matters with the clay before burning or by soaking the burnt brick in a colouring solution. If the colours are mixed with the clay before burning, the change of colour due to temperatures should be allowed for, *e.g.*, the presence of iron oxides in clay gives a red colour at low temperatures of burning, a blue and black at higher temperatures. Salt glazed brick has a glazed surface produced by salt thrown into the furnace during burning. It is largely used for lower part of walls where a non-absorbent brick is wanted or even for facing walls. Enamelled or glazed bricks are treated with a fine coating of white or coloured enamel, used for areas where reflected light is wanted, for butcher shops, dairies, urinals, certain walls in hospitals, etc.

Ordinary Flooring Tiles.

Ordinary flooring tiles are similar to bricks and are usually available in two sizes, *viz.*, $12'' \times 12'' \times 2''$ and $6'' \times 6'' \times 1\frac{1}{2}''$. The surfaces of these tiles are not even and one tile is rubbed over the other to present an even surface.

Superior Flooring Tiles.

A pattern of a superior flooring tile is made at the Madras Government Brick Fields. They are moulded in presses of finely grounded clay and have an oiled surface. They wear longer and cost more than ordinary flooring tiles. Messrs. Burn and Co., Calcutta, Henke's Tile Works, Feroke, Basel Mission Tile Works, Mangalore, manufacture common bricks, specially glazed and unglazed bricks, fire bricks, clay flooring tiles, terracotta floorings, glazed

flooring tiles. The catalogues of the firms give all particulars regarding sizes, patterns and cost of their manufacture. However, as some of their flooring tiles are often adopted in sanitary works, a short description of such tiles will be given here. Common clay flooring tiles are in great demand as a cheap flooring material for dwelling houses. These tiles are superior to ordinary country flooring tiles and cost slightly more than the latter. They are usually supplied in 3 sizes *viz.*, 9″ × 4½″ × ¾″, 9″ × 9″ × ¾″, and 6″ × 6″ × ⅞″ by the Mission Tile Works and in two sizes *viz.*, 9″ × 9″ × ¾″ and 6″ × 6″ × ¾″ by Henke's Tile Works. Basel Mission Tile works supply ornamental flooring hard-pressed tiles 6″ × 6″ × ¾″ which are durable and present a beautiful appearance. The cost of these tiles, delivered at Mangalore, varies from Rs. 30 to Rs. 45 per thousand. They also supply a superior pattern of tiles called 'Victoria cement flooring tiles.' They afford a superior flooring in a rich choice of colours. The size of the tile is 8″ × 8″ × ⅞″. Henke's Tile Works also supply terracotta flooring tiles and borders in various patterns, plain and impressed, which are largely used as a durable flooring for houses, offices, etc. The usual size of tiles is 9″ × 9″ × ¾″ and border tiles are of size 6″ × 6″ × ¾″ and 6″ × 3″ × ¾″. Ornamental encaustic flooring tiles, polished marble terrazo tiles, red Marseilles flooring tiles are also supplied by Henke's Tile Works. Messrs. T R. Boote Ltd., the Patent Tile Works, Bruslem, England, manufacture encaustic and glazed tiles of various sizes and shapes. Messrs. D. J. Keymer & Co., Calcutta are their Indian agents. For hospitals, urinals, latrines, lavatories, and in all situations where a damp-proof, and impervious lining is required white glazed tiles or Newellite glass tiles are used. The latter class of tiles is discussed in a subsequent lecture. The number of flooring tiles required per square is shown below:—

Size of tile.		Number required per square.
9″ × 9″ × ¾″	...	180
9″ × 4½″ × ¾″	...	360
6″ × 6″ × ¾″	...	400
8″ × 8″ × ⅞″	...	223

Roofing Tiles.

There are various descriptions *viz.*, the ordinary pot tile, the pan tile, the flat tile, Mangalore tile and the School of Arts tile. The ordinary pot tile otherwise known as locking tile is used as roof covering with or without flat tiles. The pan tile is similar to the pot tile but differs from it in being shorter, heavier and less curved. The ordinary flat tiles are usually 6″ × 6″ × ½″. Tiles of size 5″ × 5″ × ½″ are also sometimes made.

Mangalore Tiles.

In the market a number of varieties of Mangalore tiles is now offered. The Mangalore tiles of Basel Mission Tile Works and Henke's Tile Works are in general demand.

Basel Mission Roofing Tile: Model No. 1.

This tile is the latest production of Basel Mission Tile Works and each tile covers an area of 13¾″ × 8⅜″ and therefore only 125 tiles are required to cover one square. Reepers or battens for these tiles should be fixed 13¾″ apart measured from upper edge to upper edge. 1000 tiles weigh about 2½ tons; 250 tiles constitute a cart load; 4800 to 5000 tiles a truck load of 12 tons or 327 maunds; 2400 tiles a truck load of 6 tons or 160 maunds. The cost per 1000 full tiles, first class, is about Rs. 40 and 2nd class Rs. 35 and 1st class half tiles Rs. 20, delivered at Mangalore. The statement of the Firm as regards the advantages of this tile is as follows:—

"(1) This newest style covers a considerably large area than its predecessors, thus 125 tiles are sufficient to cover 100 square feet which required 145 of our pattern No. 3. In this manner a saving of 15% is effected. (2) As the spacing of battens (or reepers) is wider with these tiles than with previous models, a saving of 10% of battens results. (3) These tiles can be laid straight or breaking joint, as desired. In the latter case, however, half tiles are required at the ends. (4) For countries subject to heavy storms, provision is made for wiring the tiles to the battens to secure them against any heavy gale or storm. (5) Instead of lugs to keep the tiles in position on the reepers, the new tile is provided with a rib running across the full breadth of the tile, thus giving it a firmer hold. (6) The grooves at the top and sides have been very carefully designed, so that they may fit well and easily one into the other. They are both dust and rain proof. (7) All unnecessary complications in the shape of grooves and other corresponding parts of the tiles have been avoided, to facilitate fixing and to secure at all times perfect fitting."

Basel Mission Roofing Tile: Model No. 2.

The size and weight of this tile, and spacing of reepers for this tile are the same as for Model No. 3 described below. This tile is not kept in stock but is manufactured for special orders. The cost of 1000 tiles delivered at Mangalore is Rs. 36 for 1st class tiles and Rs. 30 for 2nd class tiles.

Basel Mission Roofing Tile: Model No. 3.

Each tile covers an area of 12¼″ × 8¼″ and therefore 145 tiles are required to cover one square. Reepers or battens for these tiles should be fixed 12¼″ apart measured from upper edge to upper

edge. The weight and number of cart and truck loads are the same as for tiles, Model No. 1. The cost of these tiles per 1000 delivered at Mangalore is Rs. 36, 1st class and Rs. 30, 2nd class and half tiles, Rs. 18. The statement of the Firm regarding this tile is as follows: "This tile, which was the one originally patented by us, has the following advantages: The double channel renders the surface flow more rapid, while the ridge down the centre adds greatly to its strength and durability. It will be observed that the tiles break joint, *i.e.*, the left channel of the upper tile lies to the right of that below, thus effectually preventing the smallest leakage and rendering roofing with these tiles as perfect as roofing can possibly be, certainly surpassing anything in tile-manufacture yet accomplished. Alternate courses of tiles at gable ends are furnished with half tiles. These are made right or left handed. They are exactly similar to full tiles except in width, and are sold at half the price of full tiles. To avoid mistakes, customers are kindly requested, when ordering, to state the number of half tiles required, which will be supplied in equal parts of right and left halves; thus on ordering 100 half tiles, 50 of each will be sent."

Basel Mission Patent Ridge Tiles.

Each tile is 16 inches long and covers two flat tiles on each side of ridge and weighs about 7½ lbs. The tile is sufficiently wide to ensure security from drift-rain and requires no setting in mortar. The cost of 1000 ridge tiles delivered at Mangalore is Rs. 100, 1st class, and Rs. 90. 2nd class. Ornamental ridge tiles of different patterns, sky lights, ventilating tiles, ridge or hip terminals and finials are also manufactured by this Firm.

Nowroji's Ceiling Tiles.

This ceiling tile covers the same area as roofing tile, Model No. 3 and therefore 145 tiles are required to cover one square. 1000 tiles weigh about 1½ tons and cost Rs. 40 delivered at Mangalore. These tiles are manufactured by the Basel Mission Tile Works as 'Patent Ceiling Tile No. 4' and are largely used by the Madras P.W.D. and in hospital buildings. These ceiling tiles are also made to match roofing tile Model No. 1, at an extra cost of Rs. 5 per 1,000. This is a cheap and efficient ceiling tile and the laying of the tiles is simple and requires no alteration in roof wood-work arrangement. Mr. H. Nowroji, Acting Sanitary Engineer to the Government of Madras, designed this tile and with his permission, the Firm has obtained a patent for this tile. The statement of the Firm as regards this tile is as follows: "1. Our ceiling tiles are a good protection against the heat of tiled roofs. 2. Ceilings with these tiles are much cheaper than wood ceilings. 3. The durability of such a ceiling is unlimited, whereas board ceilings are apt to be destroyed by white ants, and mat ceilings very soon require renewal. 4. The narrow and non-continuous spaces between ceiling and roofing tiles hinder rats, squirrels, etc., from entering the roof; and the cleanliness of this ceiling material prevents vermin from harbouring in it. 5. With these tiles, the ceilings of rooms and halls may be given a highly ornamental appearance, which can be enhanced by wood oiling the rafters and slightly painting the decorative design impressed on the tiles."

Henke's Manufactures.

Model 1908 Roofing tiles; 132 tiles weighing about 610 pounds are required to cover 100 square feet. Reepers or battens should be fixed 13½ inches apart measured from upper edge to upper edge. The statement of Henke's Tile Works as regards the advantages of this tile is as follows: "This pattern is the outcome of years of experience, and every detail of the work has been carefully thought out. It is superior to the ordinary 'Mangalore' pattern tile by reason of several very valuable improvements: (1) It is water-tight and dust-proof on account of the close fitting, deeply cut side groove with rebate to fit the edge of the overlapping tile, thus preventing drip and fall of dust; and the side groove is at the same time wide enough to give more play and ease in fitting. (2) It is less absorbent not only because of its excellent material and the special firing it receives in the Feroke kilns, but also on account of the complete drainage of every part of the tile, so that water cannot remain and soak into any portion of its surface. (3) It lies evenly and firmly on the roof owing to the depth of the socket which receives the curved end of the overlapping tile. (4) It is more securely hung on the reeper by the flatsided hook of clay, and it can also be fastened on high and exposed roofs by passing a wire through the small pierced ridge placed across the middle of the under-surface. (5) The double bevel on either side of the high ridge down the centre of the tile adds greatly to its appearance. (6) It is lighter than any other tile in the market and the gain in area is also considerable owing to the overlap being made much less without interfering with the efficiency of the roof. (7) As the tile covers a larger area than the Mangalore pattern etc., a saving of about 12 p. c. is effected; and as the reeper is placed wider apart than with the Mangalore pattern, a saving of about 10 p. c. in reepers also is effected. Alternate rows of tiles at gable ends are finished with half tiles, which are sold at half the price of full tiles. Henke's Model 1908 Ceiling Tiles, Glass Tiles, Sky-lights and Ventilators are supplied to fit Henke's Model 1908 fing Tiles.

Henke's Mangalore Roofing Tiles.

145 tiles weighing 725 lbs. are required to cover 100 square feet. Reepers or battens should be fixed $12\frac{1}{2}''$ apart measured from upper edge to upper edge.

Henke's Ceiling Tiles.

"Model 1908" and "Model 1902" are two patented ceiling tiles of the Firm. 132 tiles weighing about 462 lbs. of the former and 145 tiles weighing about 500 lbs. of the latter are required to cover 100 square feet of each pattern. The statement of the Firm regarding these ceiling tiles is as follows:— "As ceiling-boards are liable to be attacked and destroyed by white ants, mat ceilings very soon require renewal, and the use of flat tiles on which the roofing tiles are laid in chunam increases the cost by wood-work specially required for them, the need has long been felt for an under-tile which can be attached to the same reeper as the roofing tile giving sufficient air space. After many experiments we adopted the shape known as Henke's Patent Ceiling Tile and received a Patent for originality of design. Henke's Patent Ceiling Tiles are largely used everywhere and have come to be recognized as a simple, cheap, ornamental and effective form of double roof with continuous air space of about 2" between the tiles allowing the air to freely circulate and thus protect against the heat of the upper tile. The ceiling tiles are effectually secured against risk of slip. Extra rafters are not required, and owing to the absence of board ceilings risk of fire is greatly lessened. A large saving is also effected by the use of the tiles in the place of wood-work. With Henke's Patent Ceiling Tiles the reepers are countersunk, so that the under-surface is perfectly flat without the unsightly ridges and broken appearance presented by the tiles which are only resting on the top reeper. They are manufactured in two beautiful embossed designs and other patterns will be added. In the bright terracotta colour, for which our tiles are so celebrated, the effect is excellent. The tiles can also be painted as desired."

Timber.

Timber is the term given to wood of a size sufficient to be adopted to building and engineering purposes and is applied to no trees which measure less than 24 inches in girth. When the wood forms part of the living tree, it is called standing timber, when felled it is called rough timber, after the log has been sawn into various forms it is called converted timber; and the pieces are known as side timber, balk thick stuff, whole timber, half timber, quartering, plank, or board, laths, according to their shape and dimensions. Pieces when sawn all round are called scantlings, when sawn to equal dimensions each way they are called diesquared.

Defects In Timber.

It may be interesting to mention here some of the defects common to all trees, whether caused by the nature of the soil upon which the tree was grown or by the vicissitudes to which it has been subjected while growing. Heart-shakes are splits or clefts occurring in the centre of the tree. They are common to nearly all trees, and neither age, soil, nor situation appears to have anything to do with their origin. The splits are in some cases hardly visible; in others they extend almost across the tree, dividing it into segments. When there is one cleft across the tree it does not occasion much waste, as it divides the squared trunk into two substantial balks. Two clefts crossing one another at right angles make it impossible to obtain scantlings larger than one-fourth the area of the tree. The worst form of heart-shake, however, is one in which the splits twist in the length of the tree, thus making it impossible to convert the tree into small scantlings or planks. Star-shakes are those in which several splits radiate from the centre of the timber. This defect is found in many varieties of timber, and occurs in all ages and conditions of growth. Cup-shakes are curved splits separating the whole or part of one annual ring from another. They are most frequently met with near the root. When they occupy only a small portion of a ring they do no great harm. This deficiency of the cohesive matter between the woody layers is supposed to result from sudden changes in temperature, from the roots passing through some peculiar vein of soil, and even from frosts; violent and sudden gusts of wind and storms may also help to produce it. Rind-galls are peculiar curved swellings, caused generally by the growth of layers over the wound remaining after a branch has been imperfectly lopped off, or where the sapwood has been injured. Foxiness is a yellow or red tinge caused by incipient decay.

Characteristics Of Good Timber.

Good timber should of course be free from the defects mentioned above. In the same species of timber, that specimen will in general be the strongest and most durable which has grown the slowest, as shewn by the narrowness of the annual rings. These rings should be regular in form, sudden swells are caused by rind-galls. If the wood has colour, darkness of colour is in general a sign of strength and durability. The colour should be uniform throughout; when it is blotchy, or varies much in colour from the heart outwards, or becomes pale suddenly towards the limit of the sapwood, it is probably diseased. The fresh cut surface of the wood should be firm and shining, and have somewhat of a translucent appearance; a dull chalky appearance is a sign of bad timber. If freshly cut,

it should smell sweet; a disagreeable smell betokens decay. In wood of a given species, the heavier specimens are in general the stronger and more lasting. Amongst resinous woods, those which have least resin in their pores and among non-resinous, those which have least sap or gum in them are in general the strongest and most lasting. The heart of most sapwood is generally stronger and better in quality than the heart of trees of the same species that have little sapwood. The removal of a branch of moderate size from a tree close down to the stem, will generally be concealed by a swelling upon the exterior of the tree. Such hidden knots are frequently in a state of incipient decay, owing to the rain and moisture of the atmosphere having entered by the wound before it became closed up; and as it generally takes a long time, even many years, to completely heal it over, it would during all that time be steadily producing decay in the fibres running from the knot to the centre of the tree. The diseased or affected part when opened is often found to have spread to a very great extent, and in bad cases emits an unpleasant odour. The disease thus occasioned first attacks the sapwood and fibres immediately surrounding the centre of the knot, and then passing downwards follows the direction of the wounded branch towards the pith of the stem, after which it rises with the sap and is often communicated to other parts of the tree and does very great mischief. It will sometimes happen that this disease is concentrated or confined to the root end of the branch, producing there what is termed a druxy knot. This defect if prevented from spreading by the otherwise healthy and vigorous state of the tree during its growth must still be looked to after it is felled, since, if neglected, there being no longer any check to its development, fresh moisture will be absorbed, decay will be accelerated, and the whole log soon destroyed.

Seasoning Timber.

Timber is said to be seasoned when by some process, natural or artificial, the sap in its pores has been expelled or dried up so far as to prevent fermentation and decay from internal causes. One effect of seasoning is to reduce the weight of the timber, and Tredgold calls timber seasoned when it has lost one-fifth of its weight and says that it is then fit for carpenter's work and common purposes. He calls it dry and fit for joiner's work and framing when it has lost one-third of its weight. The exact loss of weight, however, must depend upon the nature of the timber and its state before seasoning. ~~Timber should be well seasoned~~ before conversion into scantlings. In like manner, the scantlings should be further seasoned, and after having been worked up the wood should be left as long as possible to complete the process of seasoning before being ~~painted or varnished.~~ Natural seasoning consists in exposing the timber freely to the air in a dry place, sheltered from sunshine and high winds. This is best done by stacking the timber, in such a way, that the air circulates freely round each piece at the same time, protecting it by a roof from the sun, rain, and high winds, and keeping it clear of the ground by skids. The great object is to ensure regular drying. Irregular drying causes the timber to split. The timber should be stacked in a yard, paved if possible, or covered over with ashes and free from vegetation. The skids should be placed as nearly level as possible both longitudinally and transversely, and should keep the timber at least 12 inches off the ground. If possible, the timber should be turned frequently so as to ensure equal drying all round the balks. Logs are stacked with the butts outwards, the inner ends being slightly raised so that the logs may be easily got out. Packing pieces, ½ to 2 inches in thickness are inserted between the skidding and each log, so that by removing them, any log in the tier between two layers of skidding may be withdrawn without disturbing the remainder. When a permanent shed is not available, temporary roofs should be made over the timber stacks. Boards may be stacked in the same way, laid flat and separated from one another by battens of dry wood, an inch in thickness and 3 or 4 inches wide. Any that are inclined to warp should be weighed or fixed down to prevent them twisting. Boards are frequently stacked vertically or inclined at a high angle. Natural best when time can be spared as slow the wood tough and elastic. The time required, however, is very considerable. It differs of course according to the size of the piece, the nature of the timber, its condition before seasoning and the climate of the place. Water seasoning: In consequence of the length of time required to render timber serviceable by natural seasoning, artificial methods have been adopted to effect it more rapidly. The simplest of these is water seasoning, which consists in totally immersing the timber under water about a which the sap is washed out. On out, it dried with free access of air, and turned daily. When cut up and used wet, dry-rot soon sets in. Timber thus seasoned is less liable to warp and crack, but is rendered brittle and unfit for purposes where strength and elasticity are required. Care must be taken that the timber is entirely submerged. Partial immersion injures the logs along the water-line. If timber is felled when full of sap, it benefits by this method, as the water removes the greater part of the fermentable matter and makes the wood less liable to be worm-eaten.

Boiling is another method. This operation quickens the seasoning, causes the timber to shrink less, but is expensive to use. It should only be resorted to in case of necessity, as it reduces the strength and elasticity of the timber, without adding to its durability. It is useful when joiner's work has to be executed in wood which takes a long time to season naturally. Timber should not remain too long in boiling water or steam. The time required varies with the size and density of the timber; one rule is to allow one hour for every inch of thickness. The drying after it is removed from the water should take place slowly. Steaming has very much the same effect upon timber as boiling, but the timber is said to dry sooner after the former process. By some it is considered that steaming prevents dry-rot. Scorching and charring are methods rather of preserving than seasoning timber. The lower ends of posts put into the ground are generally charred to prevent dry-rot and the attacks of worms, and the charring process may with advantage be applied to the embedded portions of beams and joists. Care should be taken that the timber to which this process is applied should be thoroughly seasoned. When green timber is charred and then placed in the ground or in an unventilated place, decay is sure to result, as the natural juices which are thus confined in the timber ferment and produce dry-rot.

Decay Of Timber.

The general causes of decay in timber are the presence of sap, exposure to alternate wet and dryness, or to moisture accompanied by heat, and want of ventilation. To prevent decay, the timber should be well seasoned before being worked up, either by the extraction of the sap, or by drying so as to remove, as far as possible, the possibility of fermentation. It should be kept clear of the influence of damp, and should have a free circulation of air about it. Timber lasts best when kept constantly dry and has a free circulation of air about it. However it becomes brittle in time, though not for a great number of years. Wood kept constantly submerged is often weakened and rendered soft, but does not necessarily decay. Some timbers are very durable when kept constantly under water, such as elm, beech, jamoon, bur and the cotton tree. The circumstances least favourable to the durability of timber are alternate wetting and drying, as is the case of timbers between high and low water mark. There are two kinds of internal decay to which timber is subjected. They are known as dry-rot and wet-rot. Dry-rot is caused by the growth of a fungus

eats into the timber, renders it brittle, and so reduces the cohesion of the fibres that they are reduced to powder. It generally occurs in confined places, where moderate warmth combined vith damp and the want of ventilation encourages the growth of the fungus. The ends of timbers built into walls are nearly sure to be affected by it unless they are protected by iron shoes, lead, or

as it prevents the passage of white ants. In the same way, dry-rot may be induced by fixing joinery and other wood work to walls before they are dry. Painting and tarring unseasoned wood by preventing access to the air and retaining dampness, has the same result. Dry-rot generally commences in the sap-wood. At first the timber swells and changes colour, is often covered with fungus or mouldiness, and emits a musty smell. When the fungus first appears on the sides or ends of timbers it covers the surface with a fine delicate vegetation. These fine shoots afterwards unite, and the appearance may then be compared to hoar-frost. It now increases rapidly, assuming gradually a more compact form, like the external coat of a mushroom. The colours of the fungus are various, sometimes white, greyish white with violet, often yellowish-brown, or a deep shade of fine rich brown. Sometimes, however, the rot appears only in the form of reddish spots, which, upon being scratched, show that the fibres have been reduced to powder. It should be remembered that dry-rot may be present in timber without any of the outward signs mentioned above. In that case, when there is any doubt, the best way is to bore into the timber with a gimlet or auger. If dry-rot is present it can generally be detected by the dust extracted by the gimlet, or more especially by its smell. Dry-rot may be propagated by the contact of an affected piece with a sound piece of timber; or by the dissemination of the germs of the fungi, which being easily carried in all directions, render the appearance of dry-rot in any part of a building particularly dangerous. Wet-rot: This form of decay occurs, in the growing tree and in other positions, where the timber may become saturated

If the wood can be thoroughly dried and the access of further moisture by painting or otherwise sheltering the timber, the et-rot can be pre

forms of decay described above, timber both in its growing and converted state is subject to the attacks of marine animals and insects. They sometimes commit such ravages on timber as not only seriously to impair any structure composed of it, but eventually to entirely destroy it. Ants: Of the ants proper or those belonging to the order hymenoptera there are three species in particular which attack timber, only one of these need be mentioned here. The black carpenter ant (Formica Fuliginosa), which prefers hard and tough wood, is found in standing trees more than

in seasoned timber. A tinge of black is seen round the holes it makes, caused by iron in its saliva acting upon gallic acid in the wood. The white ant (Genus Termes) is too-well-known in this country to require any description. It is found sometimes in Europe, but chiefly in tropical climates, more especially in Africa, India, the Mauritius and St. Helena. White ants will often destroy the whole timber work of a house without noise. They bore close to the surface of the wood but without destroying it, so that there is no visible indication of what they are doing.

Preservation Of Timber.

Timber has to be preserved from moisture, from internal decay, and from the attacks of insects. Painting: Timber may be preserved from moisture by filling the pores with oil paint. Care should be taken that the timber is thoroughly seasoned before the paint is applied; otherwise, the filling up of the outer pores confines the moisture and causes dry-rot. The same may be said with regard to varnishing and tarring. Several methods have been introduced from time to time to preserve timber from internal decay and the attacks of insects.

osoting process is the most effectu

vative at present known. It is effected by extracting the moisture and air from the pores of the timber, and forcing in a black oily liquid called creosote at a high pressure. Creosote possesses antiseptic properties; it coagulates the albumen of the wood, fills the pores with an oily liquid which ill not evaporate except at very high temperatures,

insects and fungi, expels worms, excludes moisture, prevents dry-rot, and is in every way a most effectual preservative. The timber after being dried is placed in a closed cylinder made of boiler plate. The air is then extracted from the cylinder and from the pores of the wood by means of a powerful air-pump. Creosote at a temperature of about 120° F. is then forced into the cylinder, and penetrates the wood under a pressure of 10 atmospheres or about 150 lbs on the square inch, which pressure is kept up for some days. The creosote should be heavy and rich in naphthaline, which is the more enduring material of the oil. The amount of creosote forced in depends upon the nature of the timber and the purpose for which it is intended. The sapwood absorbs it more rapidly than the heart-wood.

Selecting Timber.

Timber should be free from sap, large or loose knots, flaws, shakes, stains or blemishes of

light portion with an absence of grain near one edge indicates sap, and decays first and gets soft. The darker the natural wood, the lighter the sappy portion is, usually, when dry. Timber uniform in substance, straight in fibre

twisted, warped or waney, is classed as 'good.' Good timber should smell sweet if fresh cut, has a firm bright surface, does not clog the saw and has fairly regular and approximately circular annular rings. Good timber is sonorous when struck; a dull sound indicates decay. The closer and narrower the annular rings the stronger the timber. The colour should be uniform throughout, and not become suddenly lighter towards the edges. In specimens of the same class of timber the heavier is generally the stronger. Diagonal knots are particularly objectionable in timber for piles.

Specifying Timber.

All timber is to be thoroughly sound and well seasoned, free from sap, shakes, large loose or dead knots, waney edges, and other defects. No timber is to be fixed until it has been approved and all rejected material is to be removed from the ground forthwith.

Seasoned Timber.

Timber in which the sap and moisture are removed is termed seasoned timber. Seasoned timber is drier, lighter and more resilient or springy, and is less liable to twist, warp, or split than unseasoned timber. The advantages of using seasoned timber are (1) that it works more easily under the saw and plane, and (2) that it retains its size and shape after it leaves the hands of the carpenter or joiner. The disadvantages of unseasoned timber are (1) that it warps and shrinks, (2) that it is unsightly, (3) that it is liable to cause failures in structures of which it may form a part, and (4) that it is also very liable to decay from putrefaction of its sap.

Ascertaining Strength Of Timber.

The machines used for testing the tensional, compressional and other strengths of timber are very expensive and very elaborate, as, unless the experiments were efficiently carried out, they would be worse than useless. The object of the experiments is to find the value of C in

(1) the strength formula $W = C \dfrac{bd^2}{L \times 2240}$ and

(2) the stiffness formula $W = C \; bd^3$

where W = Safe load in tons,
b = breadth in inches,
d = depth in inches,
L = length in feet.

Teak.

Teak is the most useful

It is hard, light, and easily worked, porous,

; vary generally from 10 in. to 24 in. square, and 15 to 40 ft. long. When first removed from the ship, they are of a good cinnamon brown colour, but soon bleach in the sun. They are stacked in piles according to the

ownership, with the butt ends flush and the other ends irregular. The balks are squared up fairly straight and true, but sometimes waney at the top-end, with heart out of centre owing to the tree having been bent during growth. The ends are stamped with the mark of the Firm, often in two or three places, with the number of log, and alongside it, the trade-mark. The dimensions of the log are stamped in 1 in. figures, thus 17-2 × 2½ × 20 meaning 17 ft. 2 in. long, by 2 ft. 6 in. wide by 20 in. thick. The cubic contents are marked in red chalk. After the logs are all stacked, the invoice-mark, as 24/2783, and number of the log are painted on the end of each with white paint to identify them more rapidly.

Teak Scantlings.

The standard teak scantlings of the Madras P.W.D. with particulars of purposes for which they are ordinarily required are given below.

No.	Size of scantling in inches. b	d	Cubic foot per foot run.	Remarks and purpose for which required.
				Joists and rafters.
1	2	3½	·0486	For rafters of sloping roofs for unsupported bearing of 6ft.
2	2	4½	·0625	For rafters of sloping roofs for unsupported bearing of 8ft
3	2	5½	·076	For rafters of sloping roofs for unsupported bearing of 10ft. and also for terracing 6ft.
4	2	6½	·090	For rafters of sloping roofs for unsupported bearing of 12ft.
5	2	7	·097	For joists of terracing, bearing 8ft.
6	2	8	·1388	For joists of terracing, bearing 10ft.
7	3	9	·1875	For joists of terracing, bearing 12ft.
				For posts and struts.
8	3	3	·062	Do.
9	4	4	·111	Do.
10	5	5	·173	Do.
11	6	6	·25	Do.
				For purlins and bressummers and trusses.
12	4	5	·1388	For principal rafters.
13	4	6	·1666	Purlins of king post trusses 8ft. apart on spans from 16 to 30ft, also principals.
14	4	7	·1944	
15	5	7	·243	Purlins of king post trusses 10ft. apart on spans from 16 to 30ft.
16	5	8	·277	
17	6	8	·333	Purlins of king post trusses 12ft. apart on spans from 16 to 30ft.
18	6	9	·375	
				The above with the struts will also serve for the purlins, principals, etc., of queen post trusses for spans from 31 to 45ft.
19	3	4	·0833	*For door and window frames, etc.*
20	3	5	·1041	
21	3	6	·1250	

Safe Loads On Teak Scantlings.

For teak, the formulæ adopted in the Technical section of the Madras P.W.D. are :—

For strength.

210 bd

factor of safety of 7...I

For stiffness.

$W = \frac{210\ bd^3}{L^2 \times 2240}$, deflection of 1/30 " per foot of span II

$W = \frac{180\ bd^3}{L^2 \times 2240}$ limiting deflection to 1/40 " per foot of span III

For teak posts and struts.

$Ps. = 1/5 \left\{ 2500 - \left[\cdot 6 \left(\frac{1}{d_1} \right)^2 \right] \right\}$ implying $\frac{1}{d_1}$ = or <60. IV

Where

W = safe distributed load in tons.

b = breadth of scantling in inches.

d = depth of scantling in inches.

L = length of scantling in ft.

Ps = permissible stress in lbs.

l = length of post or strut in inches.

d_1 = least dimension of cross section of post or strut in inches.

Scantlings Of Timbers Other Than Teak.

In the Madras P.W.D. scantlings as for teak are permitted for the following timbers :—Sal, Irumbogam, Oorappo (Hopea Parviflora), Ainee (Artocarpus Hirsuta), Karamarudu (Terminalia Tomentosa), Jarrah Australian, Black butt Australian, Iron bark (white or grey) Australian, Mahogany Australian, Tallow wood Australian. The following timbers are accepted by Madras P.W.D. with the value of C = 180 in the strength formula, I above :—Irul (Xylia Dolabriformis) Pillamarudu (Terminalia Paniculata), and Poonah wood.

Metals.

The principal metals used in buildings copper, lead, zinc, and some of their alloys used in engineering structures may be divided into the following classes: A. Cast iron; arranged in order of strength, (*a*) Granular white cast iron, (*b*) Grey cast iron No. 3, (*c*) Grey cast iron No. 2, (*d*) Grey cast iron No. 1. B. Wrought iron; (*a*) Best iron, (*b*) Best Best iron, best Staffordshire iron S. C. crown, Bowling, and Lowmoor or Swedish iron; or according to forms: Flat iron, Square or Bar iron; Rod or Round iron, Tee iron, Double tee iron, Angle iron, and Channel iron. C. Steel; (*a*) Cast steel, (*b*) Mild steel; or (*a*) Blister Steel, (*b*) Spring steel; (*c*) Single shear steel, (*d*) Double shear steel, (*e*) Cast steel, and (*f*) Bessemer steel.

Characteristics Of Iron.

The great differences that exist between cast, wrought iron, and steel depend upon the amount of carbon they respectively contain. When carbon is absent, or only present in very small quantity (not exceeding 0·25 per cent.) we have wrought iron, which is comparatively soft, malleable, ductile, weldable, easily forgeable, and very tenacious, but not fusible, and not susceptible of tempering like steel. When present in certain proportions (about 1·5 to 1·8 per cent.) we have various kinds of steel which are highly elastic, malleable, ductile, forgeable, weldable, fusible in furnaces and capable of receiving very different degrees of hardness by tempering. And lastly, when present in greater proportions than in steel (about 2 to 6 per cent.) we have cast iron, which is hard, comparatively brittle and readily fusible, but not forgeable or weldable. Cast iron is six times stronger in compression than in tension and is used chiefly for parts subject to dead load only, such as columns, base-plate, and for shaped articles such as brackets, pipes, etc. Wrought iron is of nearly equal strength in tension and compression and is used for rolled sections, boilers, tie-rods, bars, bolts, nuts and rivets. Steel, at the present day, includes "all those malleable forms of commercial iron containing iron and carbon produced from a state of fusion into a malleable ingot" and is used for boiler and bridge plates when containing little carbon and for the finest cutlery and for cutting tools when containing more carbon.

Cast Iron.

Granular white cast iron is hard but being very brittle cannot be used in any large mass. Grey cast iron No. 3 contains less carbon than No. 2 and much less than No. 1. The crystals shewn in a fracture are smaller and closer than in Nos. 1 and 2. It is, moreover lighter in colour, and has less lustre. It is harder and more brittle and is employed in heavy castings. No. 2 is intermediate in quality between Nos. 1 and 3. It contains less carbon than No. 1, is therefore lighter in colour, closer in the grain, and more difficult to melt; but being harder, is better adapted for machinery, girders, and castings intended to carry weight and wherever strength and durability are required. No. 1 possesses a high metallic lustre and melts into a very fluid state which adapts it for very fine delicate castings not requiring much strength. It contains from 3 to 5 per cent. of carbon.

Wrought-Iron.

For ordinary purposes, best Staffordshire iron will be good enough. For rivets and other works requiring soft or ductile iron, Lowmoor or Swedish iron should be used. For tie rods, S.C, crown, Bowling, Lowmoor or Swedish iron should invariably be used.

Usual Forms Of Wrought-Iron.

Wrought-iron is prepared in several convenient forms for general use. A few of these will now be briefly mentioned. Bar iron, which may be readily obtained in lengths of 22 feet, includes simple sections, round, square, or flat. Square or round: The ordinary dimensions for this class of bars are generally from ½ inch to 3 inches diameter or side, increasing by 1-16th of an inch each size. If above ½ an inch diameter they are classed as rods, or if under 3-16ths inch diameter as wire. Flat Bars: The ordinary dimensions are generally from 1 inch by ¼ of an inch to 6 inches, the width increasing ⅛ of an inch and the thickness 1-16th of an inch in the various sizes. The above forms are given by angular or semi-circular indentations on the peripheries on the rollers between which the metal is passed. Various forms other than the rectangular and cylindrical such as half-round, oval, hexagon, octagon, may be given to bars of iron by the same means, that is by having the desired form of section cut in the peripheries of the rollers. But by far the most important are the angles and tee irons. Iron of these sections are largely used in many engineering structures such as *roofs*, *bridges*, *girders*, &c. The sections are made of a great variety of dimensions. Angle Iron: The ordinary dimensions are generally from ½ inch × ½ inch × ⅛ inch thick up to 8 inches × 8 inches × ¾ inch thick. Tee Iron: The ordinary dimensions range from 7/16ths inch table × ¾ inch stem × ⅛ inch thick up to 12 inch table × ¾ inch stem × 7/8 inch thick. Channel iron known also as Half H Iron, is a form frequently used in lattice girders and similar structures. It can be obtained from 5/8 inch wide × ⅜ inch high × 3/16th inch thick to 12 inches wide × 4 inches high × ½ inch thick. I Iron: This is one of the most useful sections of iron, and is known as Beam Iron, Rolled Joist Iron. It is now extensively used for fire-proof and other floors, girders of bridges, &c., and is rolled in depths of from 3 to 14 inches. Plate, Sheet and Hoop iron are made by rolling between smooth cylinders. Plate iron is made in thickness between ⅛ inch and 1 inch. The different thicknesses vary 1-16th of an inch each in succession. When beyond ¾ inch thick the plates are generally of ordinary quality. Common plates are used for shipbuilding and are called "ship plates." Best plates also are used for shipbuilding where more tensile strength is required, and for girders; Double best plates are used for the better class of shipbuilding, such as men-of-war, also for steam-boilers. Treble best plates are used in boilers of superior construction, and first-class work generally. Sheet iron is generally of a superior quality of iron and its thickness

is specified in terms of the Birmingham wire gauge (B.W.G.). When the material is of a thickness equal to or less than No. 4 B.W.G. *i.e.*, ·239 inches it is called sheet-iron; above that thickness plate-iron. Corrugated iron is produced by passing sheets between grooved rollers which force or bend them into a series of parallel waves or corrugations. These enormously increase the strength and stiffness of the sheets, and fit them for a great variety of purposes for which the flat sheets would be too weak. The sheets must be of good quality so as to stand the process, or they will crack. The general dimensions of the sheets before corrugation are 6 feet × 3 feet 2 inches, or 8 feet × 3 feet 2 inches; with corrugations, 5 inches apart, the width is reduced from 3 feet 2 inches to 2 feet 6 inches. Hoop-iron is not much used in engineering work except as an additional bond in brickwork, for which purpose it is generally about ½ inch wide and of No. 16 B.W.G. tarred and sanded. For other purposes it is made from ½ to 6 inches in width, and in thickness 20 to 14 B.W.G.

Steel.

Cast steel is like cast iron but much stronger. Mild steel is like wrought iron but more homogeneous, softer and tougher.

Blister Steel.

There are several modes of manufacturing steel. First, it may be produced by adding carbon to wrought-iron, which process is called cementation; secondly, by partially refining pig-iron, thus removing a portion of its carbon until the proper amount only remains. There are several ways in which this may be done, the result being that there are several descriptions of steel in the market. The finer kinds of steel are made of superior bar-iron, generally Swedish, by the cementation process. Iron bars after cementation process are no longer tough and fibrous, but brittle and crystalline, they are also fusible and covered with blebs or blisters. Hence the steel is known as blistered steel. The blisters are supposed to be due to the evolution of carbonic oxide arising from the combination of carbon with a trace of oxygen in the iron. When the blisters are small and tolerably regularly distributed, the steel is of good quality. Blister steel is full of cavities, which render it unfit for forging, except for a few rough purposes. It is used for facing hammers and steeling mason's points and such rough tools, but not for edge tools. Most of the blister steel made is used for conversion into other descriptions of steel. Spring steel is blister-steel heated to an orange or red colour and rolled or hammered.

Shear Steel.

By the process of cementation the exterior only of the bars is carbonised. To produce steel of uniform quality throughout its mass, bars of blister-steel are cut into short lengths, heated in bundles, and partially welded with a forge hammer. The rod so formed is heated again, sprinkled with sand and borax, and brought under the action of the tilt hammer, which by a succession of blows removes the blisters, closes the seams, and beats and amalgamates the faggots into a bar of single shear steel; such bars are more compact and malleable than blister steel, and consequently better fitted for edge tools, such as knives, plane irons, &c. If the single shear steel is doubled upon itself and again welded and drawn into bars it is called double shear steel. The process to which the steel has been subjected restores its fibrous character. It is still weldable, is more malleable, and tougher, is close grained, and capable of receiving a finer edge and higher polish than blister steel.

Cast Steel.

This term until lately was confined to steel made by melting blister steel in crucibles. The name cast-steel, however, can no longer be confined to steel so made, because Bessemer's steel, to be described presently, is truly a cast-steel. The finer kinds of cast-steel are now sometimes called crucible steel. Cast-steel is the purest, most uniform, and strongest steel, but requires more skill in forging. It is unsuited for welding, and should never be raised beyond a red heat, or it will become brittle so that it cannot be forged. It is used for the finest cutlery and for cutting tools composed of steel only.

Bessemer's Process.

Bessemer's process consists in pouring molten cast-iron into a large crucible called a converter and forcing a blast of air through it under high pressure. The blowing is either stopped at an instant determined by experience, when it is known that there remains in the iron a quantity of carbon sufficient to make the steel of the kind required, or else the blast is continued until the carbon is all removed, and from 5 to 10 per cent. of Spiegeleisen—a metal rich in carbon and manganese—is then added. The blowing is then resumed for a short time so as to thoroughly incorporate the two metals. The steel is now run into large ingots, which are hammered and rolled like wrought-iron blooms to make it sufficiently dense and compact. Bessemer steel is used for rails, tyres, common cutlery and tools, roofs, bridges etc.

Other Varieties of Steel.

Besides the varieties of steel given above, there are several other descriptions used in construction, resulting from the various modifications in the manufacturing process, and known in the market

as Siemen's steel, Siemen's Martin steel, Landore-Siemen's steel, Whiteworth's compressed steel, Tungsten steel, Chrome steel, etc.

Practical Tests For Iron And Steel.

1. Hold a piece of iron in the smith's tongs; when it is red hot strike it with a hammer on the anvil and if cast iron it will fly to pieces. If it does not, plunge it in water to cool it suddenly. If it is not hardened it is wrought iron. If it is hardened it is steel. 2. A bar slung by a string at with a mallet or billet of wood will give a clearer ringing sound for steel than for wrought iron. 3. An examination of a cold cut end will show coarse fibres and possibly some crystals in the case of wrought iron; mild steel will show a finer grain and more appearance of tenacity.

Steel Rolled Joists.

Rolled iron joists are not now made. In the Indian market there are available English joists and Foreign joists. The latter are considerably weaker than the former. Invariably English joists of standard sizes should be adopted. At the present day, wooden beams and joists are now being replaced to a great extent by steel joists.

Corrosion And Preservation Of Iron.

One of the difficulties in the use of iron and steel is the corrosion to which these materials are liable. The corrosion is most rapid on surfaces which are alternately wet and dry, and less rapid on surfaces entirely covered by water. Cast-iron and steel are more rapidly acted on by sea water than wrought-iron. Cast-iron obtains in the sand mould a covering of silicates which, if unbroken, is less liable to corrosion than clean surfaces of the metal. Acids present in some woods cause rapid corrosion of iron in contact with them. Hence, in oak, wooden tree-nails and copper bolts are generally used. The following modes are employed for the preservation of iron: 1. Dr. Angus Smith's process, which has been long used for protecting water pipes, consists in heating the iron to be coated to a temperature of 313° F. and immersing it in a bath of pitch kept at a temperature of at least 212° F. The pitch used is coal tar from which the naphtha has been removed by distillation. A little oil is generally added to the bath. 2. A tar varnish for application to surfaces which cannot be heated. The varnish consists of tar with a little tallow and resin. 3. Painting with oil paint, especially with paints which have oxide of iron as a basis.

Galvanising.

The most complete protection is obtained by immersing the iron in a bath of melted zinc. Before immersion, the iron is cleaned by being steeped for some eight hours in water containing about 1 per cent. of sulphuric acid, then scoured with sand, washed, and placed in clean water. The iron is next heated, immersed in chloride of zinc to act as a flux, and then plunged into molten zinc, the surface of which is protected by a layer of sal ammoniac. The zinc protects the iron from oxidation so long as the coating is entire.

Classification And Characteristics Of Limes.

All the calcareous cements used in masonry have lime CaO (Calcium Oxide) as their basis, in combination with other materials in different proportions. Lime is generally found in nature in combination with Carbonic Acid, Co_2 (Carbonic Anhydride), forming Carbonate of Lime, or Sulphuric Acid, forming a Hydrated Sulphate of Lime, called Gypsum, $C_aSO_4+2H_2O$. The cement formed of Gypsum is called Plaster of Paris ($2\ C_aSO_4+H_2O$), which forms the basis of most plasters, and is often added to various compositions in order to make them harden more rapidly. Carbonate of Lime ($CaCO_3$) (Calcium Carbonate) is found either pure that is, consisting of 43·6 parts of carbonic acid to 56·4 of lime; or mixed with silica (SiO_2), alumina (Al_2O_3) Maguesia (Mg O) oxide of iron (Fe_2O_3) &c., in varying proportions. White chalk and marble are specimens of the purest carbonate of lime; Lias ind many other limestones, d as specimens of the impure carbonat a piece of carbonate of lime be calcined—that is, heated to redness in air—the carbonic acid will be driven off in the process. Not only is the chemical composition of the stone changed by calcination, but the physical structure is likewise altered and the cohesion between the particles so reduced, that if the limestone is very pure it will fall to powder in the kiln. Lime after calcination becomes white or light brown, whatever was its former colour. In this state it has lost its affinity for carbonic acid, ind is termed caustic or quicklime. Slaking e chemical combination of quicklime with water. Quicklime on being wetted slakes, that is, it throws out great heat, swells up, and finally falls to a white powder, hydrate of lime (CaH_2O_2). In this state the affinity for carbonic acid is restored; but though at first it quickly absorbs carbonic acid from the air the process gradually becomes slower, and it has never been found to have recovered its full equivalent. Lime in combining with carbonic acid parts with the water it combined with in forming a hydrate. Air slaking: If quicklime be exposed to the action of the atmosphere it will gradually absorb moisture and fall to powder increase of .. Som carbonic acid is absorbed in the process, (hence lime for building purposes ought never to be air-slaked). To guard against iis sort of deterioration, quicklime should be kept in a dry place until required for use, and then

rapidly slaked with water. For slaking lime, hot water is more active than cold water, and aqueous vapour more energetic than hot water, but it would take longer to slake a large mass of lime with moist atmospheric air than with water, owing to the difficulty of renewing the water with sufficient rapidity; but nevertheless an impure lime, or a very dense lime, which has resisted the action of water will very likely crumble in moist air or steam. Setting is the hardening of lime which has been mixed into a paste with water. To form a cement with hydrate of lime it must be mixed with sufficient water to form a paste of the consistency required. After having applied a cement in the plastic state in order that it may set, or recover its original hardness when in the form of a carbonate, it would seem necessary only to subject it to pressure, and, in some cases, give it access to the carbonic acid of the air. Setting is very different from mere drying; during drying the water in the paste evaporates, but no setting action takes place. Hydraulicity: Lime or cement is said to be more or less hydraulic according to the extent to which mortar made from it will set under water, or in positions where it is not exposed to the air. Mortars made from pure carbonate of lime, such as white chalk or marble, have in themselves no property which can produce setting without the presence of carbonic acid, that is, without free access to the air. On the other hand, mortars made from impure carbonates, containing clay, magnesia, oxide of iron (Ferric oxide), &c., have within themselves, to a greater or less degree, the property of solidifying, without the assistance of the atmosphere. From this property, which enables them to harden under water, they are called hydraulic limes or hydraulic cements.

Classification Of Limes.

The limes obtained by calcining different calcareous stones may be classified according to their action in slaking and setting. The divisions, however, merge gradually the one into the other without sharp distinctions, the difference between them depending upon the nature and amount of foreign matter associated with the lime, and also upon the degree of calcination to which the stone has been subjected. The following classification is sufficient for all practical purposes: 1st. Fat, rich, or pure limes obtained from white chalk and marble, being almost pure carbonate of lime, slake with considerable energy, gain no consistency under water, remaining in a state of paste in water unchanged, but dissolving wholly in pure water frequently changed. 2nd. Poor limes, a combination of lime and sand or other inert matter; they slake sluggishly and imperfectly, and in setting resemble rich limes. 3rd. Hydraulic limes, obtained from limestones containing from 10 to 35 per cent. of clay which gives it the power of setting under water. Hydraulic limes are of much use for all the ordinary conditions of building; as on the one hand, where the building is not likely to be exposed immediately to the action of water, and where its action is not severe; or where, on the other hand, it would be improper to use pure limes. In the use of hydraulic limes, moreover, there is less danger than in the case of cements, of an unskilled bricklayer spoiling the work.

Surkhi.

Surkhi, an artificial substitute for natural earths which have the power of conferring hydraulic properties on limes, is obtained by burning good brick clay and grinding it to a very fine powder before adding it to the lime paste. Surkhi has been long known, and is extensively used in this country, to give hydraulic properties to lime. Great care is necessary in the manufacture of surkhi. It is only by experimenting with different kinds of brick that one can arrive at the best kind for this purpose. When the bricks obtainable are only such as are made of indifferent clay and carelessly burnt, which is often the case with the bricks in this country, good clay should be procured and burnt expressly. This should be done by making the clay into balls, about two or three inches in diameter, drying them, and burning them to the degree found necessary by experiment, and grinding them to an impalpable powder. This last operation is absolutely indispensable to effect the intimate union which is necessary to enable them to set under water. Those clays containing large proportion of sand are not so suitable for surkhi as those which, having more alumina in their composition, are greasy to the touch.

Portland Cement.

The cements used for building purpose are calcareous substances, similar, in many respects, to the best hydraulic limes, but possessing hydraulic properties to a far greater degree. They are distinguished from limestones by not slaking or breaking up when mixed with water after calcination. Cements are used chiefly for foundations in wet places, subaqueous work of all kinds, for important structures where great strength is required, such as dockwalls and lighthouses, for the more exposed parts of ordinary structures, such as the coping of walls, for protecting the outer faces of walls and buildings from the weather, for pointing, for thin walls where extra strength is required, for the walls of cesspits, the joints of drains, also for making concrete and cement mortar. Portland cement is by far the most important of all the cements, and receives its name from its resemblance in colour to Portland stone. It manufactured from chalk

and clay in different proportions. It may be produced from a great variety of limestones, and experience shows the exact proportions of the materials used which are most suitable. The ingredients must be so mixed that the cement is absolutely homogeneous and invariable in composition. English and many brands of Continental cements are superior to Madras cement. The Madras Portland cement is very unequal in quality and it sometimes cracks and blows when laid on the walls as plaster. Neither can the Madras cement be recommended on the score of cost; there are many brands of English cements equally cheap. So it is always safe to buy English brands. When you buy cement, see that the casks are intact, for, unscrupulous bazaarmen often open the barrels and adulterate the cement with ashes. This can be detected by taking a handful of cement and throwing it in a bucket of water. If there are ashes, it will float on the water while the cement will gradually sink to the bottom of the bucket. Cement of a whitish color is not good. It should be of a bluish grey color. When you open a new cask, the cement must be in fine powder. Sometimes you will find that it has hardened into cakes, so much so that it is often necessary to dig it out with a crowbar. When cement has hardened and caked in the cask, it is a sign of deterioration. Cost of cement varies according to the brand. In Madras the cost of a good brand nglisn cement i about Rs. Portland cement has many advantages. hard and dense mortar, much harder than lime mortar. It sets quickly in air and it sets or hardens even under water which ordinary lime mortar ~~does not do~~. One peculiar property of cement is ~~that it~~ hardens in sewage while on the other hand lime plaster corrodes and deteriorates under ~~the~~ action of sewage. The strength of Portland cement goes on increasing for a year. The strength decreases with the amount of sand mixed with it. Although the best guarantee of the quality of a cement is that it comes from a manufacturer who exercises the requisite care and attention to secure the necessary invariable quality in his product, a very slight difference in the manufacture makes a great difference in the character of the material, and hence a rigid system is necessary in order to secure the best cement. For major sanitary works, it is the usual practice to obtain the cement required by indents on the Director General of Stores, London.

British Standard Specification For Portland Cement.

"1. The cement shall be prepared by intimately mixing together calcareous and argillaceous materials, burning them at a clinkering temperature and grinding the resultant clinker. No addition of any material shall be made after burning, except when desired by the manufacturer and if not prohibited in writing, by the consumer in which case calcium sulphate or water may be used. The cement, if watered, shall contain not more than 2 per cent of water, whether that water has been added or has been naturally absorbed from the air. If calcium sulphate is used, not more than 2 per cent calculated as anhydrous calcium sulphate of the weight of the cement shall be added. Before gauging the tests, the sample to be tested shall be spread out for a depth of 3 ins. for 24 hours in a temperature of 58 to 64 degrees Fahrenheit. * * * * 4. The cement shall be ground to comply with the following conditions of fineness. 100 grammes (4 oz. approximately) of cement shall be continuously sifted for a period of 15 minutes with the following results. The residue on a sieve 76 × 76 = 5,776 meshes per square inch, shall not exceed 3 per cent. The residue on a sieve 180 × 180 = 32,400 meshes per square inch, shall not exceed 18 per cent. The sieves shall be prepared from standard wire, and the size of the wire for the 5,766 mesh shall be ·0044 inch, and for the 32,400 mesh, ·002 inch. The wire shall be woven (not twilled) the cloth being carefully mounted on the frames without distortion. 5. The specific gravity of the cement when fresh burnt and ground shall be not less than 3·15 or 3·10 when it can be proved to the satisfaction of the Engineer (or of the purchaser) that the cement has been ground for 4 weeks. 6. The cement shall comply with the following conditions as to its chemical composition. There shall be no excess of lime—that is to say, the proportion of lime shall be not greater than is necessary to saturate the silica and alumina present. The percentage of insoluble residue shall not exceed 1·5 per cent, that of magnesia shall not exceed 3 per cent, and that of sulphuric anhydride shall not exceed 2·75 per cent. 7. The quantity of water used in gauging shall be appropriate to the quality of the cement, and shall be so proportioned that when the cement is gauged it shall form a smooth, easily worked paste, that will leave the trowel cleanly in a compact mass. Fresh water shall be used for gauging and the temperature thereof, and that of the test room at the time the said operations are performed shall be from 58 to 64 degrees Fahrenheit. 8. The cement gauged as above shall be filled, without mechanical ramming into moulds, (form specified), each mould resting upon an iron plate until the cement has set. When the cement has set sufficiently to enable the mould to be removed without injury to the briquette, such removal is to be effected. The said briquette shall be kept in a damp atmosphere for 24 hours after gauging, when it shall be

placed in fresh water and allowed to remain there until required for breaking, the water in which the test briquettes are submerged being renewed every seven days, and the temperature thereof maintained between 58 and 64 degrees Fahrenheit. Briquettes of neat cement (shape specified) shall be gauged for breaking at 7 and 28 days respectively, six briquettes for each period. The average tensile strength of the six briquettes shall be taken as the accepted tensile strength for each period. For breaking, the briquette shall be held in strong metal jaws (shape specified), the briquettes being slightly greased where gripped by the jaws. The load must then be steadily and uniformly applied, starting from zero, increasing at the rate of 100 lbs. in 12 seconds. The briquettes shall bear on the average not less than the following tensile stresses before breaking: 7 days from gauging 400 lbs. per square inch of section; 28 days from gauging 500 lbs. per square inch of section. 9. The cement shall also be tested by means of briquettes prepared from one part of cement to three parts by weight of dry standard sand, the said briquettes being of the shape described for the neat cement tests; the mode of gauging, the filling of the moulds, and the breaking of the briquettes shall also be similar. The proportion of water used shall be such that the mixture is thoroughly wetted, and there shall be no superfluous water when the briquettes are formed. The cement and sand briquettes shall bear the following tensile stresses: 7 days from gauging...150 lbs. per square inch of section. 28 days from gauging...250 lbs. per square inch of section. The increase from 7 to 28 days shall not be less than 20 per cent. The standard sand referred to above is to be obtained from Leighton Buzzard. It must be thoroughly washed, dried and passed through a sieve of 20 × 20 meshes per square inch, and must be retained on a sieve of 30 × 30 meshes per square inch, the wires of the sieve being ·0164 inch and ·0108 inch in diameter respectively. 10. There shall be three distinct gradations of setting time which shall be designated as 'quick,' 'medium,' and 'slow.' Quick: The final setting time shall be not less than 10 minutes, nor more than 30 minutes. Medium: The final setting time shall be not less than half an hour, nor more than 2 hours. Slow: The final setting time shall be not less than 2 hours, nor more than 7 hours. The temperature of the air in the test room at the time of gauging, and of the water used, shall be between 58 and 64 degrees Fahrenheit. The cement shall be considered as finally 'set' when a 'needle' (of the form specified), having a flat end $\frac{1}{16}$ inch square, weighing in all $2\frac{1}{2}$ lbs. fails to make an impression when its point is applied gently to the surface. 11. The cement shall be tested by the Le Chatelier method, and shall in no case show a greater expansion than 10 millimetres after 24 hours' aeration, and 5 millimetres after 7 days' aeration."

India Store Department Specification For Portland Cement: Pattern

"1. The cement shall conform with the British Standard Specification (second issue) for Portland Cement except as regards the details hereinafter specified. Para 1. The addition of calcium sulphate is prohibited. Para. 2. Samples will be taken at the manufacturers' works by the Superintendent, India Store Depot, or his Deputy, from every 90 tons of cement, or less, ground, and they are to be forwarded carriage paid to the Oil Branch, India Store Depot. Para. 6. The percentage of magnesia shall not exceed 1·25 per cent. Para. 8. Briquettes of neat cement will be broken at 7 and 14 days, and results determined therefrom; but in order to test in strict accordance with the Standard Specification a further set of briquettes for breaking at 28 days shall be prepared. Six briquettes shall be prepared for each of the 7, 14, and 28 days' tests, and the average of the six broken at each period shall be taken as the tensile strain. Samples fulfilling the conditions of the 7-day test, failing under that of the 14-day test, but conforming with the conditions of the Standard Specification at the 28-day test, will be accepted. The average breaking strain for the 14-day test shall not be less than 433 lbs. per square inch of section. The increase from 7 to 14 days shall not be less than: $8\frac{1}{3}$ per cent. when the 7-day test falls between 400 lbs. and 450 lbs.; $6\frac{2}{3}$ per cent. when the 7-day test falls between 450 lbs. and 550 lbs.; 5 per cent. when the 7-day test falls between 500 lbs. and 550 lbs.; $3\frac{2}{3}$ per cent., when the 7-day test falls between 550 lbs. and 600 lbs; $1\frac{2}{3}$ per cent. when the 7-day test is 600 lbs. or upwards. Para. 9. The cement and sand briquettes shall have a tensile stress of not less than 184 lbs. per square inch when broken at 14 days; and the increase in strength from 7 days to 14 days shall not be less than $6\frac{2}{3}$ per cent. Para. 10. Supplies under the Contract shall be "medium" setting. 2. Notice in writing to be given to the Superintendent, India Store Depot, when the Contractor is ready to begin the grinding of the cement. 3. The cement is to be packed in casks: each cask is to contain either (1) 400 lbs., or (2) 200 lbs., cement, net, as may be specified in the orders given under this Contract. 4. The casks are to be made of sound well-seasoned fir, and are to be closely jointed. The staves of casks containing 400 lbs. cement are to be not more than 3 inches wide, and not less than $\frac{1}{2}$ inch thick. The staves of casks containing 200 lbs. cement to be not more than $2\frac{1}{2}$ inches wide, and not

less than ½ inch thick. The heads and bottoms are to be made in four pieces, and are to be not less than ½ inch thick. A cross bar 4½ ins. × ½ in. secured with at least four 1½ inch nails (one through each stave) to be nailed across the centre of each head and bottom. The cross bars to be made the full width of the head. The ends are to be segmental in shape, tapered to not less than $\frac{3}{16}$ inch at the ends, and are to pass under and be secured by the outer lining hoops. 5. Each cask is to be bound with four steel and 12 hazel hoops. The steel hoops are to be 1 inch wide by 21 S.W.G. thick, and are to be securely fastened with one ¼ inch steel rivet, the head of which is to be hammered down flat. The hoops to be firmly and evenly driven down so as to fit tightly over the entire circumference of the cask. The 12 outside hazel hoops are to be not less than ¾ inch in diameter of suitable size so as to fit the cask tightly, one hoop above and two hoops below each of the four steel hoops. Each hazel hoop is to be attached to the body of the cask by means of five nails 1⅜ inch × 12 S.W.G. 6. The heads and bottoms of the cask are to be kept in place by means of two lining hoops, each not less than ¾ inch diameter. Each hoop is to be firmly nailed to the cask by means of not less than fourteen 1¾ inch nails 10 S.W.G. thick. One of these hoops is to be fixed under and one above the head and bottom of each cask. 7. The nails used in securing the outside lining hoops are to be driven so that the points strike and are turned against the inside of the steel hoops at either end of the cask. Steel nails are to be used throughout. All nails which pass through the staves into the interior of the casks are to be well clenched on the inside. 8. The casks are to be lined throughout with stout brown paper (Pattern No. 1194/1) unless otherwise ordered. 9. A sample cask, two sample sheets of brown paper, and two sample sheets of waterproof paper, are to be submitted at the time of tendering to the Superintendent, India Store Depot, accompanied by the attached Form 153. These samples, if approved, will be retained at the India Store Depot, and will govern the whole supply of casks and paper supplied by the Contractor under this Contract. 10. The description of contents, net and gross weights, are to be marked on each cask, together with the addresses given in the schedule, and such shipping numbers and marks as may be given on the shipping orders issued by the Superintendent, India Store Depot. The shipping marks referred to are also to be shown in the column provided for the purpose in Form 214 (Shipping Details), in which must be clearly and separately stated the quantity and description of contents of each package together with its shipping number. 11. No marks of any kind other than those required by paragraph 10 of this Specification are to be made upon the cask or on the lining material inside the cask, nor is any label or indication of brand or origin to be placed in or on the casks. The marking of casks or of lining material with the firm's name or brand is prohibited, and casks so marked will not be accepted."

India Store Department Specification For Portland Cement: Pattern 1199.

"1. The casks are to be made of sound, well seasoned fir, and are to be closely match-jointed or moulded as I.S.D. Pattern Cask No. 1199. The staves of casks containing 400 lbs. of cement are to be not more than 3 inches wide and not less than ½ inch thick. The staves of casks containing 200 lbs. of cement to be not more than 2¼ inches wide and not less than ½ inch thick. The heads and bottoms are to be made in four pieces matched together similar to the staves, and are not to be less than ½ inch thick. A cross-bar 3 ins. × ½ in., secured with at least four 1½ inch nails (one through each piece) to be nailed across the centre of each head and bottom. The crossbars to be made the full width of the head. The ends are to be segmental in shape, tapered to not less than 3/16 inch at the ends, and are to pass under, and be secured, by the outer lining hoops. 2. Each cask to be bound with six steel hoops 1 inch wide by 21 S.W.G. thick. The hoops are to be securely fastened together with two ¼ inch steel rivets, the heads of which are to be hammered down flat. The hoops to be firmly and evenly driven down so as to fit tightly over the entire circumference of the casks. The top and bottom hoops to be nailed through the staves with four 1 inch nails 10 S.W.G. and each of the four intermediate hoops to be secured on the top edge with four coopers' clips. 3. The heads of the casks to be kept in place by means of two hazel lining hoops of not less than ¾ inch diameter. Each hoop is to be firmly nailed to the cask by means of not less than fourteen 1¾ inch nails 10 S.W.G. thick. One of these hoops is to be fixed under and one above the head of each cask. The bottoms of the cask are to be placed in a groove cut for the purpose about $1\frac{1}{16}$ inch from one end of the staves. This groove is to be ¼ inch deep and of suitable width to firmly hold the bottom boards. One outer lining hoop fixed with fourteen 1¾ inch 10 S.W.G. nails is to be used to secure the bottom on the outside. 4. The nails used in securing the outside lining hoops are to be driven so that the points pass through the staves just below the steel hoops at either end of the casks, and are to be properly clenched on the outside. Steel nails to be used throughout. All nails which pass through the staves, into the interior of the casks are to be

well clenched on the inside. 5. The casks are to be lined throughout with stout brown paper (Pattern No. 1194/1) unless otherwise ordered. 6. A sample cask of each description and two sample sheets of brown paper and two sample sheets of water-proof paper are to be submitted at the time of tendering to the Superintendent, India Store Depot, accompanied by the attached Form 153 These samples, if approved, will be retained at the India Store Depot, and will govern the whole supply of casks and paper supplied by the Contractor under this Contract. 7. The description of contents, net and gross weights, are to be marked on each cask, together with the addresses given in the Schedule, and such shipping numbers and marks as may be given on the shipping orders issued by the Superintendent, India Store Depot. The shipping marks referred to are also to be shown in the column provided for that purpose in Form 214 (Shipping Details) in which must be clearly and separately stated the quantity and description of contents of each package together with its shipping number. 8. No marks of any kind other than those required by para 7 of this Specification are to be made upon the cask, or on the lining material inside the cask, nor is any label or indication of brand or origin to be placed in or on the cask. The marking of casks or of lining material with the firm's name or brand is prohibited, and casks so marked will not be accepted."

Weight And Other Particulars Of Portland Cement.

1. A weighs 2. A barrel of cement weighs, net, 383 lbs. 3. A barrel of cement weighs, gross, 400 lbs. 4. A barrel of cement as supplied by the Director General of Stores weighs, net, 400 lbs. 5. A barrel of cement contains by measure, usually 4·45 c. ft. 6. A barrel of cement as supplied by the Director General of Stores contains 4·65 c. ft. 7. It improves if kept from moisture. 8. The longer it is in setting, the stronger it will be. 9. At the of a year, 1 of cement to 1 of sand is about ⅞th strength of neat cement; 1 to 2 about ½ strength; 1 to 3, about ⅓rd; 1 to 4, ¼th: 1 to 5 about ⅙th. 10. The cleaner and sharper the sand the greater the strength. 11. Strong cement is heavy, blue grey, slow setting. Quick setting cement has generally too much in its composition, is brownish and weak. 12. The less water used in mixing up the cement the better. 13. Bricks, used with cement should be soaked. 14. Cement setting water will be stronger than if kept dry. 15. Blocks of brickwork or concrete should be kept in water until required for use. 16. Salt water is as good as fresh for mixing cement.

Mortar.

Mortar is a mixture, with sufficient water added to bring it to proper consistency, of 1. lime and sand, 2. lime, sand and surkhi, 3. cement and sand. When the ingredients consist of lime and sand, the mortar is called 'Lime mortar,' Chunam mortar' or 'Chunam' (chunam is indiscriminately applied to lime as well as to the mortar). When they consist of lime, sand and surkhi, the mortar is called When sand and cement form the ingredients of the mortar it is called 'Cement mortar.' Mortar is used as a cementing material in stone and brick masonry; and on account of its plastic properties, it affords an excellent bed for stone and brick, preventing their inequalities from bearing upon one another, and thus causing an equal distribution of pressure over the bed. The quality of mortar depends upon the description of materials used in its manufacture, their treatment, properties, and method of mixing. Common mortar made with pure lime hardens slowly and only when in contact with the air. It is therefore unsuitable for damp situations, such as foundations, thick walls, or massive masonry of any description. In all such cases it remains constantly moist; when placed in positions where it is able to dry, such as thin walls, or where the water evaporates too fast, it falls to powder. It should only be allowed for inferior or temporary work, or where very slow evaporation can be secured. Hydraulic lime should therefore always be used in mortar for work of any importance. For ordinary buildings not very much exposed, slightly hydraulic limes will suffice; but for damp situations, such as foundations in moist earth, a more powerful hydraulic lime should be prepared while for subaqueous masonary, eminently hydraulic, cement will be necessary. Sand is used in for the sake of economy and to prevent excessive shrinkage. Ordinary sands are not in any way chemically acted upon by the lime, but are simply in a state of mechanical mixture. Nevertheless sand is a source of strength in fat lime mortar, for, by giving a porous structure to the mortar, it enables the carbonic acid of the air to penetrate further, and act upon a larger portion of the joint; and again it has been found that the particles of fat lime adhere better to the surfaces of the grains of sand than they do to one another. There is much difference of opinion as to what sand is best suited for mixing with lime. The general opinion of writers has been, that pit sand is better than river sand, and sea sand is the worst. From the conflicting opinions on the subject of sand we may conclude: 1st. That in making ordinary mortar, our present knowledge and experience would not justify any great expense, in order to procure sand of any particular colour or grain, or from any particular source; but that, generally, sand either too coarse

or too fine should be avoided; 2nd. that for ordinary buildings we should, if possible, use river or pit sand in preference to sea sand; but if any saving is effected by using the latter, we should not hesitate to do so, taking the precaution to wash it carefully first; 3rd. that for hydraulic buildings sea sand is just as good as any other; 4th. that in all cases it is worthwhile to take pains to clean the sand before using it, or make sure that it is clean. Proportion of ingredients: It has been already stated that sand is mixed with lime to save expense. The proportion of sand which a lime will "bear," as it is called, without making the mortar brittle, is the greater the purer the lime, and the less, the more strongly hydraulic, the lime is. For hydraulic works or foundations, equal proportions of lime and sand should be the limit allowed. The most common proportion in many parts of India are, 1 part of lime to 2 parts of sand; 1 part lime, 1 part sand, 1 part surkhi. In the P.W.D., mortar consisting of 3 parts of sand, 1 part surkhi and 2 parts lime is now generally used. Mixing: The great object in mixing is to thoroughly and intimately incorporate the sand and the lime, so that no two grains of sand should lie together without an intervening layer of film of lime. The ingredients may be mixed by hand or in a pug-mill, or under a wheel, or stones revolving on edge. The heap of slaked lime covered with sand is roughly turned over with a phara, or a shovel, and thrown into the mill, enough of water being added to bring the mixture to the consistency required. When the ingredients are thoroughly mixed and ground together, the mortar is taken away by the labourers for use on the works. On applying mortar: In applying mortars it is necessary to remember the following points:—1st. That with regard to hydraulic limes, the presence of moisture favours the setting process which is prematurely stopped, if the moisture be suddenly withdrawn. Dry bricks and most stones absorb a large proportion of moisture. To prevent this it is therefore of the utmost importance that the materials to be imbedded in such mortars, should be thoroughly soaked so that they cannot absorb the moisture from the mortar; and also in order to remove the dust from their surfaces, which would otherwise prevent the mortar from adhering. 2ndly. It is also necessary in order to prevent the too rapid drying of the mortar, after it has been applied, that work should be kept well watered, or at least damp, for sometime; and this is, of course, especially necessary during the hot season. Even in the case of fat limes, the presence of moisture for a certain time is useful, for it enables them more readily to absorb carbonic acid from the air. 3rdly. That the mortar should be as stiff as can be used without inconvenience.

Specifying Surkhi Mortar.

Surkhi, lime and sand after having been screened separately through a sieve of 144 meshes to the square inch should be spread over a well-laid clean platform one over the other in the proportion of 1: 2: 3. These should then be mixed dry three times over. The whole should then be made into a paste by the addition of water; afterwards it should be well ground in a mortar mill each filling receiving not less than 60 turns of the mill or more if necessary, to incorporate the ingredients thoroughly. The mortar should in no case be deposited on the ground. It should be used as soon as possible after it has been ground. It should be kept damp in the shade or covered up till used, and if it has become set or hardened it should be considered unfit for use and should be removed from the work.

Cement Mortar.

The sand used with the cement in making mortar is commonly directed to be clean, sharp, silicious sand. Mortar made with a coarse grained sand is stronger than one made with a very fine sand; but unsifted sand makes nearly as strong mortar as the coarsest. The usual proportion of cement mortar is 3 of sand to 1 of cement. For special works, mortar in proportions of 2 sand and 1 cement or 1 cement and 1 sand or neat cement is employed. Cement mortars are weaker than neat cement, probably because the adhesion of the cement and the sand is less than the tenacity of the cement. The larger the proportion of the sand the weaker the mortar. It appears that even with a proportion of 1 cement to 3 sand, the whole of the interstices of sand cannot be filled with cement, and as the proportion of sand increases, the proportion of unfilled space must increase and therefore there must be less section to break.

Specifying Cement Mortar.

All cement must comply with the usual tests and must be up to the English Standard Specification. The cement and sand should be measured on a clean, dry platform and laid in layers one over the other in the proportions speeified and mixed dry three times over. The sand used should be perfectly dry and free from impurities of any sort and water is to be added to the mixture, only when the mixture is required for use, and then again only sufficient quantity to make the material moist and not profuse enough to drown the cement. All cement mortar to which water has been added to be used within one hour after adding.

Mastics.

Mastic is the name given to a mixture of natural asphalt, sand and bitumen, melted and run into

moulds. Asphalts are combinations of bitumen and calcareous matter sometimes found in nature, sometimes formed artificially. Natural asphalts are superior to artificial imitations, probably because in them the bitumen is more thoroughly incorporated with the limestone or other calcareous matter. In the preparation of mastic, mineral-pitch (bitumen) must be used, not coal-tar pitch, the latter is brittle, easily softened, and weak. Good mastic should be waterproof, fireproof, tough, not brittle, and to some extent elastic It should withstand a temperature of from 140° to 160° F, without softening to any appreciable extent, and should not become so fluid as to run down below a temperature of 260° F. It is easily applied, and can therefore be used for many purposes in Engineering. It is an admirable material for the damp-proof courses of walls, also as a water-proof layer over arches or flat roofs, or for lining tanks. It is used for floors that require a very smooth surface, also for those that have to resist damp, as warehouses and godowns. When spread and brought to a smooth surface it wears well in foot-paths, and makes substantial and almost noiseless carriage-ways, but is very slippery in damp weather. It is also used for the joints of pavements of stone and other materials, and prevents the penetration of wet, but makes such pavements more noisy. There are two principal methods by which mastic may be applied to a surface: (1) by being melted, spread, and rubbed to a smooth surface; and (2) by being ground to powder, spread, and consolidated by ramming. Of these methods, the first is the more convenient in many positions, but mastic laid as compressed powder appears to be the most durable under considerable wear as in carriageways. In all cases, however, mastic should be laid on a good base of concrete or other solid material. When the surface is at a slope exceeding about 1 in 10, the asphalt is apt to run if exposed to the sun, unless a good key can be obtained.

Glue.

For commercial purposes glue is generally prepared from a variety of animal substances, but chiefly by dissolving the more soluble portions of the gelatinous tissue of mammalian animals. The softer parts of the hide and other parts of the animal are digested in a large boiler, and when the jelly thus formed is of the proper consistency, it is drawn off into moulds, allowed to consolidate, cut into thin slices or sheets, and finally dried on netting. For use, these sheets are broken up into small pieces for facilitating their action, and soaked in water for some hours before using. The soaked glue is heated in a glue pot with sufficient water to make it liquid enough for application with a brush.

Plasters.

Materials used in Plasters: Limes, Pure or Fat, are generally used for the sake of economy, as they increase in bulk during the process of slaking; they are also safer as regards blowing or blistering. Hydraulic limes are better adapted for outside plastering. When used, however, they require special attention to prevent blowing. In all cases where lime is used it should be thoroughly slaked, or it will throw out blisters after being spread. For this reason, plaster stuff is generally made long before it is required, and left for weeks to cool. Portland Cement is much used for external plastering. The lighter varieties are those best adapted for the purpose. They set more quickly, and thus save expense not only in their first cost, but also in the labour of the plaster. Sand is used in

ke of econom excessive shrink.

River sand is best adapted for this purpose; it is not so sharp or angular as pit sand, the grains having been rounded and polished by attrition. Sea sand, like river sand, is deficient in sharpness and grit from the same cause. It is, however, well suited for mixing plaster, if care is taken to have it thoroughly washed before mixing. If this is not done the plaster is liable to contract damp after being spread.

Water For Plaster.

r used for mi , like that used

mortar, should be clean and .

or salt water is objectionable as it causes damp and efflorescence on the walls. Outside plaster in this country differs very little in its nature from the ordinary mortar used in building. As, however, less strength is required of plaster than of mortar, it is usual to mix a larger proportion of sand or surkhi with the lime. The presence of the sand

beneficial up to a certain point,

the shrinkage of the plaster in

drying.

Stucco.

The name Stucco is given to various substances which differ considerably from one another. It is applied to compounds of hydraulic lime used for external work, to mixtures of lime, plaster, and other materials for forming smooth surfaces on internal walls, chiefly those intended to be painted, and to a kind of plaster worked to resemble marble. Common Stucco consists of three parts of sharp sand to one part of hydraulic lime. It was much used at one time for outside wall plastering, but of late, it has to a great extent been superseded by some of the cements already mentioned. Madras Chunam is a very fine stucco. It is laid on in three coats. The first consists of shell lime and

sand, to which is added a small quantity of jaggery water (solution of coarse sugar). The second coat is made of sifted shell lime and fine sifted white sand, without jaggery. The third coat, which receives the polish, is prepared with great care, the finest and whitest shells being selected for the lime, and mixed with from 1/4 to 1/6 their volume of the finest white sand. The ingredients of the second and third coat are ground with a roller on a granite bed to a smooth uniform surface resembling white cream. In about every bushel of this paste are mixed the whites of 10 to 12 eggs, ½ lb. of ghee (clarified butter), and a quart of dahi (sour curded milk), to which is occasionally added from ¼ to ½ lb. of powdered soapstone, which is said to improve the polish. These ingredients vary according to the opinion of the builder. The essentials in addition to the lime and sand would seem to be the albumen of the eggs, and the oily matter of the ghee, for which oil is sometimes substituted. The last coat is laid on exceedingly thin and before the second is quite dry. It dries speedily, however, and is afterwards polished by rubbing it with a piece of soapstone. Water continues to exude from the plaster for several days, which must be wiped off.

Paints.

aints are used to preserve materials from the action of heat, gases, moisture, and also to imr their appearance. There is in the market a great variety of ready mixed paints. These paints, if of approved specimens, are certainly more satisfactory than any local preparation of paints. For large works, the paints required are obtained by indents on the India Office. The paints are supplied by the India Office in 56 lbs. or 28 lbs. drums net; the thinnings can be had in 1 gallon or 5 gallon drums net. The market forms of materials for ordinary lead paint are white lead in small casks, linseed oil in drums, patent driers in tins, powder colours in casks. The white lead is first ground on a stone muller mixed with raw linseed oil to a uniform paste. The colour is then added and the mixture is then worked up with more oil and turps. The mixture should be of a uniform consistency like a thick cream and should be freed from lumps, scum, dirt, etc., by straining through canvas, if necessary. Before use it is thinned with oil and turps called thinnings and driers are also added. Linseed oil is raw or boiled. The raw oil should be limpid, pale, brilliant, mellow and sweet to the taste and with very little smell and is used for inside work. Boiled oil is thicker and more darkly coloured than raw oil and is used for outside work. Litharge, sugar of lead, red lead or Japan varnish are used as driers.

Varnishes.

Varnishes are used either to brighten the appearance of the grain in wood or to render painted surfaces more brilliant or to protect them. Gopal Varnish, Black and Brunswick black varnishes are available in 1 imperial gallon tins. Some inferior varnishes are available in 5 imperial gallon drums.

Weights In lbs. Of Various Materials, Etc., Per Cubic Foot.

Asbestos starry, 191; Asphaltum, 57; Basalt, 178; Bricks, 118; Fire bricks, 137; Bricks (pressed) in cement, 135; Brickwork in mortar, 112 to 125; Clay, 120; Clay with gravel, 154; Coal, anthracite, 90; Coal, 82; Concrete-mean, 124; Concrete, reinforced, 150; Chalk, 121; Coke, 90; Charwood, 32; Dealwood, 40; Earth, common soil, 136; Earth, loose, 93; Earth, moist sand, 128; Earth mould, fresh, 128; Earth, rammed, 100; Earth, rough sand, 120; Earth, with gravel, 126; Iron, 378 to 467; Granite, 165; Gravel, common, 109; Lime, hydraulic, 171; Lime, quick, 50; Limestone, 198; Marble, 169; Mortar, 86 to 109; Mud, 102; Paving stone, 151; Plaster, 106; Quartz, 166; Red lead, 557; Sand, coarse, 112; Sand, common, 104; Sand, damp and loose, 87; Sand, dried and loose, 97; Sand, silicious, 106; Sal, 62; Shingle, 88; Teak, 42 to 52; Trap, 169.

Excavation.

In excavating foundations for buildings care should be taken that the sides of the excavation are plumb, as far as possible. The heights at which different soils will retain a vertical face in excavations without falling in are: Clean dry sand and gravel up to 1 foot; moist sand and ordinary surface mould from 1 to 3 feet; loamy soil, well drained from 5 to 10 feet; ordinary clay from 9 to 12 feet. Chalk and rock will stand perpendicular or with a slope of ¼ to 1 height. The foundation should be excavated to the exact width and depth shown in the plan. Before work is commenced, the bottoms of the excavations must be accurately levelled, well watered, rammed and consolidated. If the excavation is done to a depth below the required level, this depth should be filled up with concrete. The excavated earth should be thrown not less than 3 feet from the outer edge of excavation. When foundation masonry is finished, the excavation should be filled in to the height of the original surface with earth, brought back from where it was temporarily deposited in regular layers of not more than 9 inches in thickness. Each layer should be carefully rammed and consolidated by the addition of water if necessary. When earth is excavated for forming embankments of tank bunds, etc., provision should be made for difference in the spaces occupied by the soil before excavation and after it is settled in embankment. The shrinkage of the different soils is about as follows: Gravel, 8 per cent; gravel and sand, 9 per

cent; clay and clay earths, 10 per cent; loam and light sandy earths, 12 per cent.; loose vegetable soil, 15 percent; puddled clay, 25 per cent. Rock, on the other hand, increases in bulk by about 50%. Thus an excavation of clay of 1000 c. ft. will form only 900 c. ft. of embankment. A rock excavation of 1000 c. ft. will form an embankment of about 1500 c. ft. depending on the size of the fragments. The natural slopes of the different soils are: clay, dry, 1·8 to 1; clay, damp, well drained, 1 to 1; clay wet, well drained, 3·5 to 1; earth, dry, 1·8 to 1; earth, moist, 1 to 1 to ·87 to 1; earth, very wet, 3·27 to 1; earth punned, ·45 to 1 to ·28 to 1; gravel, clean, ·9 to 1; gravel, with sand, 2 to 1; sand fine, dry, 1·3 to 1 to 1·6 to 1; sand, wet, 2 to 1; sand, very wet, 1·6 to 1; shingle, loose, 1·2 to 1; peat, 4 to 1 to 1 to 1.

Concrete.

Concrete is an artificial compound, generally made by mixing lime or cement with sand, water, and some hard material such as broken stone, gravel, bits of brick, slag, in various proportions as required. These ingredients should be thoroughly mixed and allowed to harden so as to form a sort of conglomerate. The lime or cement, sand, and water combine to form a lime or cement mortar in which the hard material is imbedded so that the result is a species of very rough rubble masonry. The rubble or broken material is sometimes, for convenience, called the aggregate and the mortar in which it is encased, the matrix. Beton is a name given by some authors to any concrete made with hydraulic lime or cement. s, a distinction is made between the two, concrete being the name given when the materials are all mixed at once, and beton when the mortar is made separately. Practically, however the word concrete covers any form of artificial conglomerate. The matrix: The lime or cement, sand, and water should be so proportioned that the mortar resulting from their mixture is the best that can be made from the materials available. Concrete should not be made from rich limes, unless such as are improved by being combined with pounded brick, &c. If, however, circumstances compel the use of rich lime, it must be reduced to a fine powder by slaking or grinding, and be evenly sifted through a very fine sieve, then mixed with a proper proportion of aggregate and wetted, not over-much, but sufficiently for its complete conversion into a hydrate. In some cases, the mortar is mixed separately, just as if it were to be used in building brickwork or masonry, and then added to the aggregate. Hydraulic limes are best adapted for concrete purposes in nearly all situations. Eminently hydraulic limes should be used for concrete foundations in damp places, and, in the absence of cement, for subaqueous work of any kind. They also require to be reduced to a fine powder by grinding and slaking, and passed through a No. 40 sieve. Such finely powdered lime can be kept for a long time if packed in well made paper-lined barrels, so as to exclude air and if kept dry.

Cement Concrete.

Portland cement concrete is adapted for all positions, especially for work under water, or where great strength is required; also in situations where the concrete has to take the place of stone as in facing to walls, coping, &c. The aggregate is generally composed of any hard material that can be procured near at hand, or in the most economical way. Almost any hard substance may be used when broken up, such as stone, slag, brick, &c. If there is any choice, preference should be given to fragments of a somewhat porous nature, such as pieces of brick or limestone rather than to those with smooth surfaces as flint or shingle, as the former offers rough surfaces to which the cementing material will readily adhere. Size and shape: The aggregate should be broken into smaller angular pieces so as to pass through a ring 1½ to 2 inches in diameter. Experiments show that the best results are produced when the size of the pieces is a minimum. With regard to shape, angular fragments are generally preferable to rounded pieces; the former fit better into one another and slightly aid the coherence of the mortar, forming a sort of bond, while the latter are simply held together by the tenacity of the cementing material. Again, the size of the pieces of which the aggregate is formed, influences the contents of the void space between them; it is therefore necessary to adjust the proportion of lime and sand, so that no vacuities will occur in the mixture. Unless the mortar is of such a description that it will attain a greater hardness than the aggregate, the object should be for the concrete to contain as much broken material and as little lime as possible. A cubic yard of aggregate of an average size of 2 inches contains nearly 11 cubic feet of voids, and a cubic yard of shingle contains about 9 cubic feet of voids. A mixture of stones of different sizes reduces the amount of voids and is often desirable. The contents of the voids in any aggregate may be ascertained by filling a water-tight box of known dimensions with the material, and measuring the quantity of water poured in so as to fill up all the interstices; or by weighing a cubic foot of the aggregate and comparing its weight with that of a cubic foot of the solid stone from which it is broken. Proportions of ingredients: The best proportions for the ingredients of a concrete to be made with any given materials, may easily be found by trial in each case, by finding the contents of the voids in a cubic yard as above. In practice, however, a little more mortar

than is actually required to fill the voids is added in order to compensate for imperfect mixing. There is a great variety in the composition of concrete used by different Engineers under various circumstances. If hydraulic lime is used the proportion of ingredients may be estimated as varying from 1 volume of aggregate and 1 volume of mortar, to 2 volumes of aggregate to 1 volume of mortar. For Portland cement concrete the usual proportions are 1 cement, 3 sand, and 6 broken stone; and under water the concrete usually consists of 1 Portland cement, 4 to 6 of broken stone and sand, the larger proportion of cement being necessary in order to make up loss by scour. Laying: After mixing, concrete should be carried to the place where it is to be laid, gently tipped into position, and carefully and incessantly rammed in layers of from 6 to 12 inches in thickness. The old practice of tipping concrete from a height is now abandoned. It was attended with injury to the mixture from the tendency of the heavy and light portions separating while falling, and thus leaving the concrete not uniform throughout its mass. Each layer should be left till it is perfectly set before another layer is put upon it. And it is essential that the layer should be horizontal; if not, the water trickling off will carry the cement with it. Each layer, after it is thoroughly set, should be carefully prepared to receive the one that is to rest upon it. Its surface should be carefully swept clean, wetted, and made rough by means of a pick. This is specially necessary if it has been rammed, for in that case the finer stuff in the concrete works to the top and also a thin milky exudation, which will, unless removed, prevent the next layer from adhering. Joints between the layers are the most important points to be attended to in concrete. When the proper precautions have not been taken they are found to be sources of weakness, like veins in rocks, and the mass can easily be split with wedges. When there is not time to allow each layer to set before the concreting is continued, it is better to ram it as quickly as possible, and, before it is set, to add the layers above it. Anything is better than to allow the layers to be disturbed by ramming after they have commenced to set. When concrete has to be laid under water care must be taken that it is protected during its passage down to the site of deposit, so that the water may not reach it until it is laid. This protection is afforded sometimes by shoots, by boxes, or by skids, which can be opened from above when they have reached the spot where the concrete is to be deposited so as to leave it there. A similar method has been followed in filling the well-cylinders forming the piers of many of the Railway bridges in this country. Sometimes the concrete is filled into bags and deposited without removing the bags. Concrete is also made into large blocks. These are allowed to set on shore, and afterwards carried and deposited at the site.

Use Of Concrete.

Concrete has long been used for the foundations of structures of all kinds, and for filling in the spandrels of arches, or the hearting of walls; and engineers have looked upon such works as the only legitimate field for its use. But of late years, from a better knowledge of its properties, and from the fact that more reliance can now be placed on the composition of the cement used in its formation, concrete has been used for many other purposes. Whole buildings are now constructed of concrete; sea and wharf walls and even piers and arches of bridges. Concrete may be used either by making it in moulds into great artificial blocks of stone, and using them as ordinary large stones as in masonry; or monolithic walls may be built of fresh concrete rammed tight between frames.

Specifying Concrete.

Sand to be used should be moderately coarse in texture, clean and have angular grit and should be entirely free from loam, clay, dust, and organic matter or impurities of any description whatever and must, if necessary, be washed. Cement must be fresh, uncaked and finely ground and must be up to British Standard Specification. Broken Bricks: For concrete the bricks should be broken to pass through 1½ inch ring in any direction, *i.e.*, the maximum dimension or diagonal must not exceed 1½"; the muddy particles and fine dust should be removed by screening and washing; the impurities must also be removed. Vitrified brick, if available, is preferable to ordinary brick. The broken bricks should be well wetted with water, then turned over and allowed to drain, before being used for concrete. On no account should underburnt brick be used. Broken Stones: The stones should be broken to pass through 1½" ring in any direction, *i.e.*, the maximum dimension or diagonal must not exceed 1½"; the stone shall be clean, hard, of cubical structure as far as possible and free from all impurities. Particles smaller than ¼ inch and flat chips should be screened out and should not be used in the aggregate and with the sizes of the remaining coarse stone varying from small to large, the coarsest predominating. The stone should be washed and all impurities, muddy particles and fine dust must be removed; it should be well wetted with water and turned over to drain before being used for concrete. Concrete to consist of an aggregate of clean broken stone or brick of a moderately porous nature, adhered by a matrix of either cement or lime mixed with sand in such proportions as ordered. The aggre-

gate and the matrix should be in such a ratio as the Engineer shall deem fit to suit the circumstances of the case. No more concrete should be mixed than can be laid in position on the day of mixing. When Portland cement is used, the concrete must be laid immediately after mixing. The materials after having been properly gauged, the materials forming the aggregate will be laid out on a clean platform with even depth throughout and covered over by the cement or mortar as the case may be in the proper proportion and the whole turned over thrice in the dry state and should be ridged around a central cavity prepared to receive the water. The water should be applied from a watering can with a rose and the ingredients should be turned over under the spray, so that each and every portion of the mixture may receive a due proportion of water. Water must not be thrown on to the concrete from buckets or chatties. Attention should be paid that the quantity of water used, while not profuse enough to drown the concrete, should be just plentiful enough to act as an efficient intermediary between every particle of the aggregate and every particle of the matrix. The concrete when wet should be turned over not less than four times and may be turned over oftener if considered necessary for proper incorporation. Concrete should be laid in the work in layers not greater than 6 inches in thickness and it should not be thrown from a height, as the larger and heavier portions thereby become separated from the matrix; it is to be well worked against the sides of the trenches and the whole must be well rammed, properly levelled, and brought to an even creamy surface. Concrete should, on no account, be rammed after it has commenced to set. Where concrete face has become dry and a further layer has to be added thereon, such surface should be thoroughly washed, and should be well wetted previous to the application of the new layer so that the two layers may combine into a homogeneous whole. The concrete whilst setting should be tested from time to time by picking up small portions to ensure that a proper set has taken place. If interstices occur on the surface of a layer they must be filled in with thin mortar before the next layer is laid. The concrete should be kept wet for at least seven days after it has been laid by means of a watering can with rose attached.

Reinforced Concrete.

Reinforced concrete, ferro concrete, armoured concrete, or beton frette, etc., is the name given to a class of concrete introduced within the last few years. Iron rods or bars are inserted in suitable positions in concrete forming a practical and economical combination of concrete and steel, the former material being utilised to resist the compressive stresses, with the necessary steel bars embedded at the points where tensile stresses occur. In ferro-concrete work good workmanship and materials are essential. The cement used for concrete of this description should be the best English Portland Cement. The quality, testing and mixing of the materials, the sizes and positions of the reinforcements, the construction and removal of centerings and lastly the laying of the material in place and the thorough punning of the concrete to ensure solidity and freedom from voids demand high class labour skilled in this method of construction in addition to very careful superintendence of Engineers. When reinforced concrete is allowed for foundations, the usual specification for this work is as follows: The stone jelly should be such as pass through a sieve of $\frac{3}{4}''$ mesh and the concrete mixed in the same manner as specified for cement stone jelly concrete. The percentage of reinforcement should in no case be less than ·5 of the section of concrete used. The expanded metal sheets should overlap at least 3″ and all the joints carefully tied with wire and the sheets should break joints if laid in two layers as also at the corners of the buildings. The first course of concrete should be laid, then the expanded metal after the first layer is levelled; then the next layer and so on as provided in the estimate or otherwise specified by the Engineer. The concrete should be rammed only after it is fully laid, so that it may form a hard block, the expanded metal adhering to the concrete. With regard to other particulars, the work should be carried out as for laying cement stone jelly concrete. The cement should be fresh, uncaked and finely ground and should stand all the standard tests.

Description Of Brickwork.

Brickwork construction is classed first class when it is built of table moulded bricks, 2nd class when it is built with ground made bricks of first class quality specially made for it and 3rd class with sound ground made bricks available locally. In practice, brickwork is classified under the following heads depending on the character of bricks and the mortar used: (1) Sun-burnt brick in clay. (2) Country, 2nd sort, brickwork in clay. (3) Country 1st sort, brickwork in clay. (4) Country, 1st sort, brickwork in chunam. (5) Country, 1st sort, brickwork in surkhi. (6) Country, 1st sort, brickwork in cement. (7) Table-moulded brickwork in chunam. (8) Table-moulded brickwork in surkhi. (9) Table-moulded brickwork in cement.

Bond In Brickwork.

Bond in brickwork is the arrangement of the bricks in such a manner that continuous vertical joints are avoided and the bricks in one course cover

the joints of the bricks in the adjacent course. English and Flemish bonds are the two classes of brickbonds. These two classes of bonds are illustrated in plate 11. The English bond consists in laying all headers in one course showing on face over one, two, three or four stretcher courses. Bricks laid lengthwise to a wall are called stretchers, those transversely are called headers. Each horizontal layer is called a course. Flemish bond consists of alternate headers and stretchers in every course, that is, each course contains both headers and stretchers, the headers of one course being central between the stretchers of the adjacent courses.

Specifying Brick In Mud.

The execution of work in bond and other details to be as for country bricks in surkhi mortar but laid in mud. The mud used should be unmixed purities, should be well tampered, if p proportion of sand to be added as required. The mud and sand should be worked down with water and puddled till it is perfectly free from lumps and of the consistency of thick paste.

Specifying Brick In Chunam.

The execution of work in bond and other details to be as for bricks in surkhi mortar but laid in chunam mortar usually consisting of 2 of sand and 1 of chunam.

Specifying Country Brick In Surkhi.

Bricks should be of dimensions approved by the Engineer, say ($8\frac{3}{4}'' \times 4\frac{1}{2}'' \times 1\frac{3}{4}''$). They should be of uniform size and colour, well burnt and well shaped. The bricks are to be well soaked in water before use on works. They must not absorb more than 15 per cent. of their own weight of water after having been submerged for 24 hours. The method of procedure and the points to be observed are the same as in the case of table moulded bricks excepting that joints may be allowed to a thickness not exceeding $\frac{1}{2}$ an inch.

Specifying Table-Moulded Brick In Surkhi Mortar.

Bricks are to be hard, squarely shaped, well burnt, even in size and of the best quality. Bricks for facing should be carefully selected for their evenness of colour and face and the visible arrises must be undamaged. The bricks should be soaked in tanks or tubs at least 24 hours before being used except when the mortar is of fat lime and sand. As work proceeds it will be kept thoroughly wetted until the mortar has set firm and hard which will be from 15 to 30 days. On closing the work for the day small ridges of mortar, $1\frac{1}{2}$ inch high will be set all round the upper surface of the masonry and filled with water which will be left to soak in during nights. On Sundays and holidays they must be kept continuously filled with water. The bricks should be laid flush in mortar, every course should be thoroughly grouted and no bats or half bricks should be used unless where absolutely necessary as closers to complete the bond. All joints to be thoroughly flushed up as the work proceeds unless plain struck joints are specified; in the latter case the specification for plain struck joint must be followed. The bed joint should not exceed $\frac{3}{8}''$ thickness; the height of four courses of brick work should not exceed the height of the same bricks laid dry by more than $1\frac{1}{2}''$. All horizontal joints should be straight, level and even and all faces to walls should be worked true and plumb. The wall should be carried up at one uniform level throughout but where breaks are unavoidable they will be made in good long steps so as to prevent cracks appearing between the new and old work. In any case no part of the wall should be left more than three feet lower than the other. Round pillars should be built of quadrant-shaped bricks and when they are of considerable height, flat circular discs of stone of the same diameter of the pillar and about three inches in thickness should be introduced, so that every pillar has two discs, *i.e.*, a pillar of 12 feet high should have one disc at 4 feet and another at 8 feet, from the ground level so as to ensure a proper bond. The exterior facing should be pointed with a neat weather joint; all internal walls excepting those otherwise described to be left rough for plaster. Mortar as stiff as possible must be used on brickwork.

Specifying Brickwork In Cement.

The cement and sand to be mixed dry in the proper proportions and water in sufficient quantity to form a stiff paste to be added only when the mortar is being used. All mortar to which water has been added to be used up before work is stopped. All finished portion of the masonry works to be left flooded after the day's work. The bed joints not to exceed 1/4" in thickness unless used to bond with brick in mortar used alongside. Execution of work in bond to be the same as for brick in mortar.

Description Of Stone Masonry.

Generally stone masonry is classed as (1) random rubble, (2) coursed rubble and (3) ashlar. In practice, the different classes of stone masonry are: 1. Laterite stone in clay, chunam, surkhi, or cement. 2. Random rubble in clay, chunam or surkhi. 3. Coursed rubble, 3rd sort, in clay, chunam, surkhi or cement. 4. Coursed rubble, 2nd sort, in chunam, surkhi or cement. 5. Coursed rubble, 1st sort, in chunam, surkhi or cement. 6. Ashlar, perfectly squared blocks set in chunam, surkhi, or cement. In plates 12 and 13 are

illustrated some classes of stone masonry. In some cases, walls built of bricks, rubble or concrete are faced with ashlar. (see figs. 32 and 33 in plate 13). The methods of construction will be found detailed under the different heads.

Specifying Laterite Masonry.

The stone should be the best procurable, free from any admixture of white earth. If possible, it should be dug from the quarry sometime before use and be allowed to harden before being placed in the work. The stone should be quarried true and square to the sizes ordered. The least thickness of stones should be 7 inches and the breadth of stones should not be less than the thickness and the length not less than twice the thickness. The stone should be laid in the work header and stretcher alternately and arranged to break joint at least 3 inches.

Specifying Random Rubble Masonry.

Every stone should be carefully fitted so as to form neat and close joints. Joints not to exceed ½ inch in thickness. The stones should be roughly hammer-dressed and uniformly coloured and of pretty equal size on the face. They should be carefully laid and solidly bedded in mortar, and should tail back and bond well into the backing and should not be of greater height than either breadth or face, or length of tail into the work. One header or through stone should be inserted in, at least, every square yard of the face and should run right through the wall if not more than 2 feet thick; if more than 2 feet thick, a line of these should be laid from face to back which shall overlap each other at least six inches. The stones should be arranged to break joint as much as possible, and long vertical lines of jointing should be carefully avoided in the face work. In the case of thick walls, the filling between the face stones should be with large stones, and not with small chips of stone, even if they are slightly thicker than the height of the course. Stones should be thoroughly wetted before being laid in the work and for which each mason should be supplied with a vessel for wetting stones. The proper watering of all masonry should be carefully attended to. Tops of walls to be built up to the upper surface of battens so as to leave no space for rats. Plinth offsets on the interior faces only should be kept at least 6 inches below floor level to allow of the paving (if any) coming up to the face of the superstructure and to prevent cracking of the pavement, over the offsets. As paving is done subsequently, this point should always receive attention.

Specifying Coursed Rubble Masonry, 3rd Sort.

In each course, headers, hammer-dressed of the entire height of the course, are to be placed 5 feet apart, each header to be of a breadth not less than the height, and to tail into the work at least 3 times its height. Between the headers, each course is to be built of smaller stones not less than 2" thick, of which there may be two or three in the height of the course. These stones need not be dressed, but should be as flat bedded as possible; the side joints need not be vertical, but no side joint shall form an angle with a bed joint sharper than 60°. No stone should be less in breadth or length than its height and care must be taken to make the stones in the different courses break joint. All stones to be set full in mortar. In walls of two feet and under, these headers to be through stones. In thicker walls a line of headers to be laid from face to back which should overlap each other at least six inches. Care should be taken not to place the headers of successive courses above one another.

Specifying Coursed Rubble Masonry, 2nd Sort.

This description of masonry consists of a facing of hammer-squared stones on one side, with a backing of rubble masonry built in courses of the same height as the facing, and bonding properly with it. All stones to be carefully set full in mortar. The face work should be as specified for coursed rubble, 1st sort. The stones in each course need not, however, all be of the same height, but not more than two to be used in the height of the course, and the joints may be as much as 1/2" in thickness. No course should be of greater height than any of those below it. The hearting or backing should consist of uncoursed rubble masonry, which should be carried up simultaneously with the facing, the face stones being backed as soon as laid, but each course need not be completely levelled off. In all respects, other than those specified above, the facing and backing should correspond with specifications for coursed rubble, 1st sort, and uncoursed rubble respectively.

Specifying Coursed Rubble Masonry, 1st Sort.

The stones should be laid in horizontal courses not less than 6" in height. All the stones in each course should be of equal height, and all courses of the same height unless otherwise specified, in which case no course should be thicker than any course beneath it. All stones to be set full in mortar. The face stones to be squared on all joints and beds. The beds to be hammered or chisel-dressed, true and square, for at least 3 inches back from the face, and the joints for at least 1½ inches. The face of the stones to be hammer-dressed, and "bushing" not to project more than 1½ inches. No pinnings will be allowed on the face. All side joints should be vertical and beds horizontal, and no joint should be more than 3/8 inch in thickness. No face stone should be less in breadth than its

height, or should tail into the work to a length less than its height, and at least $\frac{1}{3}$rd of the stones should tail into the work at least twice their height, or in thick walls three times their height. Through stones should be inserted between 5 and 6 feet apart in the clear in every course, and should run right through the wall when not more than 2 feet thick. When the work is more than 2 feet thick, a line of two or more headers or stones should be laid from face to back, which should overlap each other at least 6 inches. Stones should break joint at least half the height of the course. The work on the interior face should be precisely the same as on the exterior face, unless the work is to be plastered, in which case the side joints need not be vertical. The interior of the wall to consist of flat-bedded stones carefully laid on their proper beds and solidly bedded in mortar, chips and spalls of stone being wedged in wherever necessary, so as to avoid thick beds or joints of mortar, care being taken that no dry work or hollow space is left anywhere in the masonry. The face-work and backing should be brought up evenly, but the backing should not be levelled up at each course by the use of chips.

Specifying Ashlar Masonry.

For fine ashlar, every stone should be fine-tooled on all beds, joints and faces, full, true and out of winding if the surfaces are plane or to uniform curves or twists if required by the design. In the case of rough-tooled or bastard ashlar, the faces exposed to view should have a fine dressed chisel draft, 1 inch wide all round the edges, and be rough tooled between the drafts and on all beds and joints. For rustic or quarry-faced ashlar the exposed faces of the stone between the drafts should be left rough as the stone comes from the quarry; but no rock face or "bushing" to project more than 3 inches from plane or drafts. No stone should be less than 12 inches in height and be less in breadth than in height or less in length than twice its height. All the courses should be of the same height unless otherwise specified, in which case, no course should be thicker than any course below it. In walls $2\frac{1}{2}$ feet thick and under, the headers should run right through the wall. The bond should consist of headers and stretchers laid alternately in every course, the headers being arranged to come in the middle of the stretchers above and below. Fine ashlar work will probably only be required for beds of machinery. For fine ashlar the mortar joints should not exceed $\frac{1}{8}$ inch in thickness. For other ashlar work it should not exceed $\frac{1}{4}$ inch in thickness. For ashlar facing of walls built of rubble, bricks or concrete, the faces of stones to be rough tooled, rustic or chamfered as desired. The backs of stones may be left rough in the state they leave the quarry. No stone to be less than 18 inches in length, 15 inches in breadth and 8 inches in height. When the height of a course is more than 10 inches, the breadth of the stones should not be less than $\frac{1}{3}$rd more than the height of the course. The beds and joints should be rough tooled, true and square for at least the same distance from the face as the thickness of the course in which they occur. Bond stones should be inserted in every course at 5 or 6 feet apart carrying them right through in walls not more than $2\frac{1}{2}$ feet thick If more, they should overlap at least 6 inches.

Cut Stone Work.

The stone should be of the best granite. It must be of uniform structure and colour, dense and hard. If broken the stone must present a bright, clean, and sharp texture, without loose grains and free from any dull and earthy appearance. Cut stone joints should be of about $\frac{1}{8}$ inch and shall never exceed $\frac{1}{4}$ inch in thickness, the thickness of the joints varies with the nature of the dressing. The stones should be laid on their natural beds. Large stones should be tried first in their beds before setting and should then be raised and withdrawn, the bed finally cleaned, well wetted and the mortar laid; the stone should then be brought near its place and gently lowered upon wedges, by the withdrawal of which the stone is brought exactly on to its bed. Mallets of suitable size must then be used to drive the stone well home to its place. All stones should be well wetted before setting and should be set in the best manner. Every stone should be bedded with complete full squeezed out joints either in cement or lime-mortar, and all work in contact with brick to be plastered with similar mortar to protect from stains, and all brick backing of same to be set in similar mortar.

Foundations.

In every case, it is necessary to ascertain the nature and character of the soil on which it is proposed to construct a building by digging trial pits at its proposed location. The least depth of foundations is 3 feet. The breadth and depth of foundations are fixed with reference to the character of the soil at site and the weight of structure to be built thereon. Rock, gravel and sand are good foundations. Clay is generally treacherous and precautionary measures are necessary for foundations in clay soils. Made ground, even though it may have lain undisturbed for years should not be trusted for the support of any building, especially buildings of much weight. In order to spread the weight of the building over a larger area and produce an equality of settlement, brick walls are made wider at the base. The most up to-date practice is to make each course of brick $\frac{1}{2}$ a brick wider than the course immediately

above, so that if the wall is a $2\frac{1}{2}$ brick wall, the first course immediately below the wall will be a 3 brick course, the next course below will be $3\frac{1}{2}$ brick, and so on. Below the lowest brick course provision is generally made for a bed of good concrete varying in depth from 2 feet to 7 feet as required with 6 inches projection on either side of the lowest course of brick footing. When constructing stone foundations, the breadth of the steppings ought in no case to exceed one fourth the averag length of the header stones. The question of safe loads on foundations is one of practical judgment and too much reliance should not be placed on a table of safe loads, for the reason that it is a difficult matter to find which of the soils named in the table corresponds with the soil that is about to be built on. The following table of safe loads in tons per square foot on different soils and materials is inserted here to serve as a guide :—

Rock, 9·0; soft rock equal to good concrete, 3·0; very soft rock, 1·8; moist clay and sand, 1·36; coarse sand and dry clay, 2·25; clay, soft or loose filling, 1·00; good ordinary clay, wet, 2·00; good ordinary clay, dry, 3·00; clean sand, confined and dry, 3·00 to 4·0; clean sand, confined and wet, 2·00; gravel and hardened sand, 2·00 to 5·00; loamy and sandy soil, ·5 to ·75; red earth, 3·00; mooram, 4·00; lime concrete, 3·00 to 3·50; brick and lime masonry of good, hard burnt common brick, 2·00 to 5·00; cement concrete, 1 : 1 : 3, 35; cement concrete, 1 : 2 : 4, 32; cement concrete, 1 : $2\frac{1}{2}$: 5, 29; cement, concrete, 1 : 3 : 6, ·25; cement concrete 1 : 4 : 8, 19; black cotton soil, made earth, and clay not permanently moist, ·25.

Foundations In Soils Requiring Special Treatment.

The following three soils require special treatment, and should not be given a greater weight than 0·25 ton per square foot. (*a*) Black cotton soil. (*b*) Made earth. (*c*) Clay, not permanently moist. Black cotton soil: Wherever this soil overlies rock or firm compact soil at depths not exceeding 8 feet, the foundations should be taken down to the compact stratum. Where this is not the case, and sand or gravel is easily procurable, the black cotton soil over the whole area under the building, and for an additional width of 3 feet all round, should be removed and sand or gravel, well rammed substituted. Where such material is scarce, the foundation trenches should be excavated to the full depth of the black cotton soil, and the space occupied by the latter filled in with sand or gravel well rammed. Foundations in black cotton soil should always be ut in during the hot weather, when cracks in th worst and can be more readily seen nd rendered harmless by the precautions described above. If a water-bearing stratum of sand or gravel, or both mixed, underlies the black cotton soil to considerable depth, probably the best plan is to found any structure that it is unavoidably necessary to build thereon on wells. Terrace roofs should be avoided in buildings on black cotton The site of any structure should always be dr i.e., an apron 6″ to 9″ thick, and not less than 10 feet wide, of gravel should be laid all round a building, at a slope of 1 in 20, and drains dug to carry away the drainage therefrom. The foundations of structures built in black cotton soil should be as far as possible uniformly loaded *i.e.*, one part of the foundation should not be made to bear a greater load than another. This can generally be done by increasing the width of the foundations in direct proportion to the load. Made earth: This class of soil should never be built upon if it is possible to avoidance is impossible the precautions enumerated above in connection with black cotton soil should be followed, except where made earth is unmixed with clay, it is probably best to found a structure built thereon on a concrete platform not less than 3 feet in thickness. This form of foundation is, however, entirely unsuited for soils which vary in the amount of moisture present. Clay soil: Any soil with clay in it alternately wet and dry, is especially treacherous to build on. The precautions laid down for black cotton soil should be carefully followed in all such cases.

Thickness Of Walls Of Buildings.

Compared with thickness of walls in England, the thickness of walls in India is about 2 to 3 times the former. The Indian climatic conditions and proverbial bad materials and workmanship account for this condition. Thin walls as in England would allow of heat passing through them. Undue thickness might of course be avoided. Walls of single storied buildings are usually 2 bricks thick and of double storied buildings are 3 or $2\frac{1}{2}$ bricks thick at ground floor and 2 or $1\frac{1}{2}$ bricks at first floor

Prevention Of Damp.

In order to prevent damp rising from the ground through walls, a water proofing or damp-proof course is laid in external walls. The best position in the wall for the damp-proof course is the course in the wall, the top of which is at the floor level of the buildings. In England where the flooring consists of wood planks on joists and where the basement is not filled in with earth or sand as is done in India, (the damp-proof course) may be inserted in the wall at any intermediate level between floor level and ground level. The damp proof course in walls of houses, the basement of

which with earth should be at floor level. slabs laid in cement and pointed with cement to the full depth of the slabs form an excellent damp proof course. 6" thick, asphalt, glazed bricks laid in are other suitable damp proof courses. Some engineers consider a course of $\frac{3}{4}''$ cement (1 cement and 2 sand) as a damp-proof course.

Arches.

Figs. 1 and 2 in plate 14 show (1) flat and relieving arch and (2) a cambered brick arch. The object of an arch is to support the super-incumbent weight over an opening. The usual forms of arches are (1) flat, (2) segmental, (3) semi-circular and (4) Got type of arch is the strongest form of arch, while flat arch is the weak-

According to the class of material used, arches are classed as (1) brick arches and (2) stone arches. The other form of arches, *viz.*, Jack-arches will be discussed under 'roofing.' Brick-arches: The usual rise of arches (see fig. 1, in plate 14) for segmental openings of 60° over doors, windows, etc., is span The area of a segment of $60^\circ = \text{span}^2 \times \cdot 091$; length of intrados $= \text{span} \times 1\cdot 047$; length of extrados $= (\text{span} \times \text{thickness of arch}) \times 1\cdot 047$. For spans up to 3 feet two rings of bricks and for spans above 3 up to 8 feet 3 rings would suffice. The bricks should be laid in concentric rings the voussoir joints should not exceed $\frac{1}{2}''$ in thickness and they should be perpendicular to the tangent of the curve at all points. In laying, the bricks should be well pressed into their beds so as to squeeze the mortar out and leave the joints thin. Bricks for skew back joints should be specially moulded or cut so as to radiate truly; joints in two concentric rings should not come in the same vertical plane. The archwork should be evenly and quickly done and kept thoroughly moist so that no portion of the arch hardens or sets before the whole arch is completed. For arches which are not constructed of specially moulded bricks but with ordinary rectangular bricks, the best bricks of the respective classes should be selected. All joints should be truly summered. The bricks should be set with as close joints as possible and the rings should be carefully bonded. In all centerings the upper bearing surface should be very correctly formed to the figure of the intrados of the arch and the centering should be sufficiently strong to bear the weight of the material of the arch together with the workmen and tools placed upon it without either sinking or changing its form at any time during the construction of the arch. Centres should be slackened within 24 hours after the arch is completed under normal conditions. Care should be taken that the centering is not lowered while the mortar in the last finished joints is still so soft that it will be squeezed out, but at the same time should be lowered while the mortar is still moist so as to allow the arch to slightly compress itself and bring all its joints into fair bearing. In all cases the centerings should be lowered before the facing spandrel and outside parapet walls are built upon the arches. Stone Arching: Rubble arching, coursed rubble arching and ashlar arching are the three classes of stone arching. Rubble arching consists of slabs, hammer dressed approximately to the proper shape with joints not exceeding $\frac{1}{2}$ to $\frac{3}{4}$ inch. In the case of coursed rubble arching the stones should be rough tooled on beds and joints and no stones should be less than 6 inches on their least dimension and the mortar should not exceed $\frac{1}{4}$ inch in thickness. Ashlar arching consists of stones dressed full and true set in fine mortar not exceeding 3/16 inch in thickness. No stone should be less than 10 inches in its least dimension; in all cases, the stones to be of the entire thickness of arch.

Doors And Windows.

Internal doors should not, as a rule, be less than 3 feet wide and 6 feet 6 inches high. A common of doors as used in India is that width plus thi half feet. The size of doors named on drawings will be the size between the outside of the door frames. Doors of greater width than 3 feet are generally divided into two parts that is, are "hung folding." Doors are described according to the arrangement of the shutter forming the door and are also called "right handed" or "left handed" according as they open inwards to the right or to the left. The usual forms of doors are (*a*) panelled, (*b*) panelled and glazed, (*c*) ledged or battened, (*d*) plain planked, (*e*) framed and braced, (*f*) planked and iron-barred and (*g*) venetianed. Doors will generally be paid for by a rate on the area between frames, (outside dimensions). Size of windows will depend on the object of the room in which they are to be placed. The window sill should generally be about 2 feet 6 inches from the inside floor level. Windows may be provided either for the purpose of lighting only or for both ventilation and lighting. In the former case, they may be (*a*) fixed so that they cannot be opened, and in the latter (*b*) hinged on either side, (*c*) hinged to top or bottom rail, (*d*) hung on pivots near their centres. The methods (*c*) & (*d*) are generally adopted for clerestory windows or windows high up in the wall, but method (*b*) is adopted in the case of ordinary windows.

Flooring.

The different classes of flooring are many and an attempt to describe every class of flooring would

serve no useful purpose. The essential condition of a flooring is that it should be impervious. The kinds of flooring which will be considered as satisfying minimum sanitary requirements for special buildings as medical institutions, markets, slaughter-houses, latrines and dhobie khanas will be discussed later on under the description of each building. Under this head, I will give a list of the different classes of flooring with present cost per square at Madras and describe some of them. 1. Flooring with concrete 4" thick well rammed and plastered with cement ½" thick, (3 to 1) per 100 square feet, Rs. 10-0-0. 2. Flooring with 8" country paving tiles and pointed with cement per 100 square feet, Rs. 13-10-0. 3. Flooring with 12" country paving tiles and pointed with cement per 100 square feet, Rs. 16-0-0. 4. Flooring with stock brick in cement plastered with cement ½" (3 to 1) on 3" concrete per 100 square feet, Rs. 16-0-0. 5. Flooring with compressed tiles 6" square and pointed with cement per 100 square feet, Rs. 20 4-0. 6. Flooring with Cuddapah slabs on 4" concrete and pointed with cement per 100 square feet, Rs. 23-0 0. 7. Flooring with asphalt ½" thick laid on 4" concrete per 100 square feet, Rs. 24-0-0. 8. Flooring with asphalt, ¾" thick laid on 4" concrete per 100 square feet, Rs. 32-0-0. 9. Flooring with semi-polished Cuddapah slab on 4" concrete and pointed with cement per 100 square feet, Rs. 36-0-0. 10. Flooring with teak boards planed to 1¼", plain jointed per 100 square feet, Rs. 50 0-0. 11. Flooring with teak boards rebated and filleted 1½" thick per 100 square ft., Rs. 56-0-0. 12 Flooring with teak boards tongued and ploughed 1½" thick per 100 square ft., Rs. 57-0-0. 13. Flooring with 2 line dressed granite paving stones laid on 4" of brick concrete and neatly pointed with cement or asphalt per 100 square ft., Rs. 68-0-0. 14. Flooring with polished Cuddapah slabs 2 ft. square on 4" concrete and pointed with cement per 100 square ft., Rs. 75-0-0. 15. Flooring with half white marble and Cuddapah slabs polished on 4" bed of concrete per 100 square ft. Rs. 75 to 100. 16. Flooring with white marble slate 2 ft., square polished on 4" concrete per 100 square ft. Rs. 125-0-0. 17. Flooring with Europe encaustic tiles over 4" bed of concrete per 100 square ft., Rs. 100 to 125. 18. Flooring with Marseille flooring tiles 7⅞" × 7⅞" laid on 4" concrete and pointed with cement per 100 square ft., Rs. 47-0-0. 19. Flooring with white glazed 6" × 6" plain tiles per 100 square ft., Rs. 90-0-0.

Specifying Flooring.

The basement should be filled in with sand and not with earth. The flooring as specified should be laid with a slope of 1 in 40 towards the outside or towards the vents for the discharge of rain-water, but the sloping should be commenced from the centre, in cases such as passages or corridors which generally have openings on both sides. Concrete should be laid over this to the specified depth. Cuddapah slabs of 1½" or 2" thick should be laid in mortar on top of concrete. The slab need not be of the same dimension, but no slab be of lesser dimension than 3 feet × 2 feet except they be required for the ends of the floor. The slabs should all be dressed true and square and should be laid with ½" joint to the full depth of the slab. The finished surface should be true and the joints should be well pointed with cement mortar in the ratio of 1 of cement and 1½ of sand. When rubbed Cuddapah slabs are to be used, the surface and joint should be rubbed smooth and true and the joints should not exceed ⅛" in thickness. When square tiles are to be used, the same method of procedure is to be adopted.

Marble Flooring.

The marble should be of the best of its kind. The cement should be old plaster mixed with marble dust. The joints in slabs and blocks should break with each other.

Pressed And Ornamental Tiled Flooring.

Tiles to be used for flooring should be of approved patterns. After the concrete bedding has been laid, as in the case of Cuddapah slab flooring, it should be evenly covered with a coat of finely ground mortar and evenly levelled. The tiles should be carefully set in Portland cement on surface thus prepared and pointed fine. The flooring should be wetted for a week after laying. The surface of the floor should not be rubbed if it would destroy the glaze and smoothness of the tiles.

Boarded Flooring.

Boarded flooring to be of the best teak boards, thoroughly seasoned and of the greatest length procurable. Boards to be of the thickness specified in the estimate, and not less than 6 inches in width to be tongued and grooved or tongued and ploughed, as may be specified in each case. Heading joists to rest upon the joists below to break joint with one another and to be rebated and tongued together. Each board is to be secured to its proper position by 2½" screws to the joists below. The heads of all screws to be counter-sunk and the exposed surface then planed smooth.

Asphalt Flooring.

The ground should be first made perfectly firm and level and covered with good concrete to a depth of 2" for ordinary floors and to 4" for floors of godowns, etc. A large caldron or iron pot having been provided and fire lighted under it, put into it broken pieces of asphalt of small size so as to facilitate easy fusion. Mix the asphalt with a stirrer in such a way that the pieces at the bottom are constantly

brought to the surface. If the asphalt is not naturally mixed with sand or lime then, when the whole quantity is thoroughly fused, sand or grit is to be added in the proportion of two parts of sand to one part of asphalt. The sand should be added gently and constantly stirred for the purpose of keeping contents of the boiler properly mixed and to prevent their becoming burnt and clinkered to the sides and bottom of the boiler. When fit for use, the compost will emit jets of light smoke and freely drop from the stirrer. It should then be raised as rapidly as possible to prevent its becoming overburnt. Having provided gauges, *i. e.*, long strips of hard wood or iron of the thickness of the coat to be laid, place one with weights on it parallel to one of the sides of the floor to be covered and at a distance of about 3 feet from the wall. In this place the spreader kneels and as soon as the compost is poured down it is to be spread with a trowel to even thickness. To facilitate this work an ordinary floating rule 3½′ in length may be used to level the compost to the thickness of the gauge and any unevenness is easily corrected by the trowel. Before the compost becomes hard a small quantity of very fine sand should be sifted over it and well rubbed into it. When one strip down the room is finished a similar strip next to it is skipped and two gauges laid at the proper width along the edges of the next or third strip which is filled in similar way to the first. Thus when the alternate strips are cool, the gauges are to be removed and intermediate strips filled in.

Reinforced Pabco Flooring.

Reinforced pabco should be laid over any smooth solid surface. The total thickness when completed should be about one quarter of an inch full and should be composed of two layers of maltha asphaltum, one layer of felt and one layer of two ply "pabco" sheeting. Flashings should extend up walls at least 4," each layer of reinforced pabco should be separately flashed up round or through parapet walls. All angles should have an apron piece on the underside embedded in asphaltum and fire joined edges. All cover flashings should be tuck pointed with cement where let into walls, etc. All cover flashings should be fire jointed at edges. All joints should have a two-inch overlap. Each layer of pabco asphalt felt should have maltha asphalt flown between all joints. Pabco (two ply) roofing should have all joints fire jointed. All joints should be broken. A thoroughly trained man should supervise all work. First coating: Boiling floatine (mineral asphalt) should be flown over the entire surface of the roof about one-eighth of an inch in thickness. Second coating: Pabco asphalt saturated felt sheeting should be rolled into the asphalt before setting, overlapped 2″ at joints. Third coating: Boiling floatine (mineral asphalt) should be flown over asphalt felt one-eighth of an inch in thickness. Fourth coating: Two ply pabco roofing should be rolled into asphalt before setting, overlapping 2″ at joints. All joints should be made good with a blow lamp. All works should be left perfect and water tight on completion.

Paripan Filler: White.

For filling: To be used as supplied by the company with a knife and to be rubbed down with pumice and water. For stopping: Some dry white lead is to be mixed with the filler and then to be used with a knife. For priming coats: To 7 lbs. of paripan filler are to be added three to four gills of turps and mixed thoroughly. The turps should be measured in and not guessed at. The whole should be stained to shade of Paripan Japan of the selected colour. Before applying the Paripan Japan, the surface should be rubbed down with glass paper and dusted off. After removal of lid, the filler is to be kept covered with water, to prevent formation of skin.

Paripan Japan White Painting.

The contents of the can should be well stirred before use, and should be poured through a piece of muslin to eliminate any particles of skin which may have formed on the surface. This japan should be laid upon a zinc white under coat, and in all high class work, Paripan under coat white is recommended. During cold weather, the cans should be stored in a warm room and after Paripan Japan has been applied, care should be taken that frost is not allowed to attack the work until it has become quite dry.

Paripan Finishing White Fat.

This finishing should be applied in a thin coat and be well-worked out under the brush; care must be taken not to put on too much at a time. Before applying a second coat, the surface of the former coat should be rubbed down with powdered pumice stone, just sufficiently to take off the gloss, the finishing will then flow more freely on the work.

Newellite Glasstile-Flooring And Walling.

Materials to be used: Best Portland cement and either washed river sand or sharp pit sand in the following proportions: For rendering: Three of sand to one of cement. For fixing: Two of sand to one of cement. The walls should be floated with sand and cement in the above proportions and plumbed and the surface left well scored. In the case of old white-washed walls, the greatest care should be taken to remove every particle of the white-wash and the joints should be carefully raked out without which the necessary cohesion

between the walls' surface and the rendering will be wanting and failure may result. All wood such as lintels, etc., must be covered with expanded metal lathing before rendering. The face of the glass tile finish is three-eighths of an inch from the face of the rendering. It is advisable to gauge the cement over-night and to work it up fresh in the morning. Great care should be taken to batter the tiles equally; they should then be fixed with as close butting joints as possible, worked in solid, and carefully patted to ensure an absolutely even surface. When cutting is required an ordinary glazier's No. 2 opal diamond should be used. By means of wooden templet, the tiles can be cut to fit any curve.

Public Works Department Specification For The Use Of Artificial Stone Blocks In Buildings.

"(1) The blocks shall be used as received from the factory and no cutting or otherwise altering the shape or strength of blocks is to be permitted. "Special blocks," *i.e.*, those not usually manufactured shall be supplied to all works where the contingency is foreseen, but, in special or urgent cases, the application of cement plaster to form mouldings, small cornices, etc., may be permitted. (2) Walls shall be built plumb and true, the faces of block to be uniformly in one plane. (3) The joints between blocks shall be of one part English Portland cement, with three parts of sharp sand to pass a 30×30 mesh screen. Horizontal joints shall in all cases be 3/16" thick. Thicker joints horizontally with the uniformly moulded blocks are quite unnecessary. Fifteen courses of blocks in mortar shall occupy a height of 10 feet. Vertical joints shall be 3/8" thick. Joints shall be pointed in fine cement mortar, the joints to be flush with the face of the wall, so that all joints shall be invisible when distempered or painted. (4) Blocks slightly damaged in transit to work-site shall be repaired with 3 : 1 mortar, as above specified. Badly cracked or otherwise faulty blocks shall be rejected. (5) All reinforced beams and door lintels shall have not less than 8 inches full bearing at ends. (This will, incidentally, eliminate the use of small blocks as closers.) (6) All blocks shall be well-watered immediately before being put into the work."

Roofs Classified.

Indian roofs are of two kinds, flat or terraced, see figs. 3, 6 and 7 in roofs plate 14; pent or lean-to roofs; see figs. 4, 5, 8, 9, 10, 11, 12 and 13 in plates 14 and 15. Flat roofs are divided into two classes, *viz.*, terrace roofing and jack-arch-terracing. Pent roofs are of the following descriptions, (1) flat and pan tile roofing, (2) plain pan tile roofing, (3) roofing with Mangalore tiles with flat tiles, (4) roofing with Plain Mangalore tiles, and (5) corrugated iron roofing. Classified with reference to the frames on which are laid any of the above roofing materials, they may be considered under the following heads:

(1) Couple roof,	(see fig. 8 in plate 14).
(2) Couple close roof,	(see fig. 10 in plate 15).
(3) Collar Beam roof,	(see fig. 9 in plate 14).
(4) King-Post roof,	(see fig. 12 in plate 15).
(5) Queen-Post roof,	(see fig. 13 in plate 15).

formed of two inclined rafters meeting upon a ridge board to which they are nailed, the feet being nailed or notched to the wall plate. This roof is suitable for small spans up to 11 feet. Couple close roof is an improvement on the couple roof formed by connecting the feet of the rafters by a tie beam, which prevents them from spreading and thrusting out the walls and can be economically used in spans up to 14 feet. If the tie beam has to support a ceiling, it may be held up by an iron King rod from the ridge. Collar Beam Roof is a variation of the couple close roof where greater headway is required, the tie beams being raised half way up the rafters. It is not such a good form as the rafters tend to bend in the middle and thrust out the walls; may be much improved by adding a tie beam or tie rod at the foot of the rafters, when the collar beam becomes a strut and forms a good roof up to 16 feet span. King Post Roof is adopted for spans from 16 to 26 feet. The King post forms a ipport for the tie beam, and the struts prevent the principal rafters from bending in the middle. If the span is greater than 26 feet, the tie beam will require more than one support. This is given by means of Queen posts in Queen Post Roof.

Terrace Roofing.

One course of terrace bricks should be laid on onally across the joists and extending for 6 inches over the inner edges of the walls. The mortar should in this case consist of one lime to 1½ of sand. When this is set, a layer of brick concrete 3 inches thick made up of fine broken bricks (½ inch. gauge) and lime in the ratio of 2 : 1 should be laid over it. The concrete should be laid evenly and true to the required slope and should be thoroughly beaten with light wooden knives. The beating should continue until the mortar has almost set and until the knives make no impression and readily rebound from the surface when struck on it. Whilst beating is in progress, the concrete should be liberally sprinkled with lime water. Should this surface, during the process of beating, become so uneven that water lodges, it should be picked up and fresh concrete added as may be necessary. After the concrete, three courses of flat tiles should be laid diagonally, breaking joint in

mortar of 1 lime, 1 sand and 1 surkhi; the joints of the top layer should be left open to afford a key for the plaster. Plaster in the ratio of 1 lime, 1 sand and 1 surkhi should be applied over all and smoothly finished. When Madras terracing is provided, the woodwork consists (1) of joists, (2) joists with wood beams, (3) joists with Rolled Steel Beams. When the length or breadth of a room to be terraced does not exceed 12 feet, provision is made only for joists. The joists are usually spaced 18 inches apart from centre to centre. The usual dimensi for teak joists, spaced 18 inches apart are: 2 inches × 5½ inches, 2 inches × 7 inches, 2 inches × 8 inches, 3 inches × 9 inches for spans of 6 feet, 8 feet, 10 feet and 12 feet respectively. In the case of rooms of widths of more than 12 feet, the usual practice is to introduce a wood beam or rolled iron girder dividing the longer dimension into a number of bays, and joists are placed across. For instance, there is a room 40 feet long and 16 feet broad and it is proposed to terrace the room. At eight feet intervals, wood beams or iron girders are placed supported on the two lengthwise walls. The joists are supported by the beams and the end joists by the beams and cross walls. The beams should be inserted into walls with air space as shown in figs. 16 and 17 in plate 15. The invariable practice now is to use rolled steel girders instead of wood beams.

Jack-Arch Terracing.

This method of roofing is shown in plate 95. Rolled steel joists are placed at distances shown in the following table; on these should rest one ring of 4½ inches brick archwork in mortar, 2 inches concrete, and plaster ½ inch at top and bottom.

Span in feet.	Span for arch in feet.	Rise of arch in inches	Size of girder.
10	5	6¼	R.S. B 11= 7" × 4" × 16 lbs.
12	5	6¼	R.S. B 12= 8" × 4" × 18 lbs.
14	5	6¼	R S. B 15= 9" × 4" × 21 lbs.
16	6	7½	R.S. B 17=10" × 5" × 30 lbs.
18	6	7½	R.S. B 20=12" × 5" × 32 lbs.
20	6	7½	R.S. B 20=12" × 5" × 32 lbs.

The weight of archwork is taken as 100 lbs. per sq. ft. and 80 lbs. per sq. ft. are assumed as live load. All roof should have sufficient slopes to discharge rainwater about (1 in 40). The end joists of the floor in the case of small roof and the two joists nearest each end in the case of large roof should be tied together with either flat iron 1¾ inches by ⅜ inch rivetted to the bottom flanges, or round iron 1" diameter bolted through the web. The archwork in some cases is turned with terrace or country bricks with concrete and three courses of flat tiles identically as in terrace roofing.

Flat And Pan Tiled Roofing.

Over the rafters, reepers 2" × ½" should be nailed at central distances suited to the size of the flat tiles; the joints should be lap joints over the rafters. The flat tiles should be first dipped in white wash and laid in mortar. Over this course pan tiles well burnt, well shaped and free from cracks should be placed; before using, these should be soaked in cow-dung water for 12 hours. The first layer should be laid over the flat tiles in rows touching one another and overlapping lengthwise for a little more than half their length, the concave side being upwards; the second layer should then be laid with the converse side upwards and covering the joints between the rows of tiles of the previous layer. Ridges and hips should be covered with special tiles set in mortar. Valleys should be lined with galvanized iron 24 gauge sheeting, 3′ wide; no nails or solder to be used; the depth of the trough made by the sheeting should not be less than 9". Strips of plaster 9" in width and 2" in thickness should be laid down the slopes at intervals of 4′ to 6′. Similar strips should be laid around the eaves, care being taken not to obstruct the discharge of rain-water; the object of these strips is to localise the effect of wind and so to prevent whole roof from being stripped. At the junction of the roof with a wall, the tiles should be let into the wall to a distance of 3" and a 4½" projection with mortar should be formed above the roof surface. Eaves boards to be 1" thick and 1" deeper than the vertical section of the rafters; it should be screwed to the ends of the rafters when shown on the drawing.

Mangalore Tiled Roofing.

The roofing should consist of Mangalore tiles laid on battens 2" × 1" securely nailed to the rafters with lap joints at the centres of rafters. The distance apart of battens may be determined by the gauge of the tiles. Before laying the tiles, care should be taken to see that the roof is even and true; the eaves batten should be 3" × 2" shaped to the slope of the roof. The tiles should be first class, well burnt and true: no model previous to that of Henke's 01 should be allowed; either the modifications of Henke's latest model and of the Basel Mission tile should be permitted. The tiles should be laid from the eaves towards the ridge after the fitting of the battens. The ridge and hip tiles should be laid in surkhi mortar. The valleys should be boarded with teak ½" thick and should be protected with thick lead or zinc sheeting 3 feet in width and 9" in depth. A wind tie 3" × 2" should be fixed by bolts and nuts over the eaves and at the ends over the gables.

Roofing With Mangalore Tiles Over Flat Tiles.

Over the rafters, reepers 2″ × 1″ should be nailed ; on these reepers should be placed a layer of flat tiles in mortar (the tiles having previously been dipped in whitewash), then the Mangalore tiles should be laid as above described on a layer of mortar 1″ thick which has been spread over the flat tiles. The roofing should be completed similarly to Mangalore tile roofing.

Corrugated Iron Roofing.

Corrugated sheets should be laid (on approved rafters or trusses of teak or iron) with laps not less than 6″at the ends and two corrugations at the sides; vertical laps should be turned away from the rainy quarter. Soldering and all unnecessary contact with lead should be avoided; Windle's patent clips should be used instead of rivets, etc. The holes for rivets should be punched from the inside towards the outside at the distance of about 9″ at the sides and at every third corrugation at the ends. Sheets when fastened with best galvanized rivets and lead washers should be carefully set on the purlins and fastened to them by galvanized iron screws and washers or by bolts or other fasteners of approved pattern. The fasteners should be spaced about 5 feet apart horizontally and in the same line in the direction of the slope over each purlin. All bolts and screws should be set in white lead. All holes should be punched in the ridges of corrugation and provision for expansion should be made by drilling the holes in the underneath sheets, a slightly larger size than is necessary, to allow the fasteners to pass through. Hips and ridges should be galvanized iron or zinc with 9″ lap on either side. In open sheds and verandahs iron bars 2″ × $\frac{1}{4}$″ of continuous length should be bolted to the purlins so as to act as wind ties.

Specifying Timber And Wood-work.

Timber used should be L. R. teak of the best quality unless any other description of timber is specified; it is to be properly seasoned and free from sap, shakes, strikes, large loose or dead knots, wavy edges or other defects. All timbers of large scantlings to be sawn out immediately before beginning construction of any building so that the shrinkage may take place before they are fixed in the building. All workmanship to be of the best description, all joints to fit accurately without wedging or filling, and to be framed and trussed in the best possible manner and fitted with all necessary wrought iron ties, straps, bolts, screws, etc., as shown on the drawings. The rates for different items of work should include their delivery at the site and their fixing in position. Planking to be supplied with straight and square edges, it should be rebated, ploughed, tongued or dovetailed as may be directed. All wood-work when put up on the work should be of the dimension specified, and no allowance for wastage will be allowed. The contractor should not be paid for dimensions supplied beyond those specified, and the length of each piece should be measured over-all so as to include projections for tenons or scarfs. Before wood-work is placed in position the written approval of the officer in charge should be obtained and in joinery work such approval must be obtained before priming. No timber should be painted, tarred, oiled or otherwise treated without previous permission of the officer in charge. Any truss or framed work should be put together in the ground and submitted to suitable tests before being placed in position. All timber resting on or bedded in masonry should have an open space (see figs. 16 and 17 in plate 15) of at least $\frac{1}{2}$ inch on either side of it for ventilation. Glue should not be used in any joint or frames unless ordered as it will absorb moisture in damp weather and so set up decay. Portion of work in which glue is used for joints should be rejected. Beaumontique composed of white lead, litharge and boiled oil in the proportion of $\frac{1}{2}$: $\frac{1}{2}$: 4, respectively should be used in the place of glue for joints when ordered. The doors of the kitchen should open away from the fire place; no wood-work of any sort should be set within 2 feet of a fire place or flue. The whole of the rough hardware, of whatever kind, that may be necessary to execute in good and substantial manner the whole of the work specified for the joiner and carpenter, is included under wood-work wrought and put up. Brass screws should be used for all brass fittings and iron screws for all iron fittings. Bolts, butts, hinges, locks, latches, pulls, stays and fasteners should be those of approved patterns.

Specifying Wrought Iron Work.

All wrought iron work to be carefully, cleanly and soundly forged, not over-heated nor burnt. All plates, sheets and bars to be tough, fibrous, and of the highest smithing quality. They should be of exact dimensions shown on the drawing and should be of the uniform thickness or section specified. They should be free from blisters, scales, laminations, buckles, twists and all other defects. No iron should be used in girders or similar work, that will not bear an ultimate tensile stress of 22 tons to the square inch, and all bolts, tie rods, tension bars straps, etc., should be tested with a proof tensile stress of 22 tons to the square inch. All corresponding parts of similar spans and trusses to be made exactly similar and interchangeable. All edges of all plates, and the ends of all single irons, and bars must be planed dead true to the dimensions, or where planing is not possible they must be dressed off fair with hammer, chisel and file. No rough edges

straight from the sheers should be permitted anywhere throughout the work. All rivet holes which are to be filled in the field are to be drilled, all the holes may be drilled or punched, any plate or bar in which the holes are not accurately in place should be rejected. The holes to be drilled to a diameter which shall not exceed by one-twentieth the diameter of the rivet which it is to receive. All iron work must be temporarily erected complete so that accuracy of fit and perfection of workmanship may be assured. All the iron work excepting the bolts and rivets is to be scraped free from rust, scale and dirt and is then to be covered with boiling hot linseed oil. It is afterwards to be painted with two coats of good oil paint, the first being red lead and the second that which shall be named by the officer in charge. All steel must comply with the usual tests and must be up to the English Standard Specification.

Specifying Cast Iron Work.

All castings should agree in dimensions with those shown in the drawings. All castings should be sharp and clean, free from all blow holes, honeycombing, broken surface, lumps, box-putting ridges and other defects and when cold must be thoroughly dressed with chisel and file. Immediately after each article is cast, it should be protected in such a manner that its strength may not in any way be diminished by too rapid or unequal cooling.

Plastering.

Plastering consists in applying different compositious resembling mortar to walls or ceilings, in thin layers so as to form smooth surfaces for the sake of appearance and cleanliness. Plaster is often cover outside as well as inside composition of a plaster will depend very much upon the way it is used; that which is lied externally requires to be stronger and more le to withstand the weathering effects of the atmosphere than the less exposed internal plastering. External plastering should be discouraged, as it is oo often used to conceal bad work, and it quickly looks shabby and requires continual repair. Yet, many seem to think that a structure is not properly finished, whatever style the building may be, unless it is plastered. It may, however, be laid down as a principle that good masonry, composed of well burnt brick and good mortar requires in general no external plaster to preserve or beautify it. There are, however, many cases in which it is quite legitimate to use plaster. If the building is not of great importance, or if the masonry is not intended to be exposed to unusual strain, the saving in India is so great by using under burnt bricks in place of pucka ones, or by using mud in place of mortar, that houses are constantly built of this description, and with such it is necessary to use plaster. Again, plaster should be used externally when there is any object in having the surface of the brick work smooth, as in the case of a brick vault or arched roof. If the outside be left unplastered, rain would penetrate the finest joints, and in such a case plaster is employed, not so much to protect the masonry as to oppose a smooth surface instead of a rough one, for the water to run off. When used in inside work the plaster may either be laid on the face or may be spread over a screen of laths fixed in any position. The latter operation is called plastering, the application to the wall itself being called rendering.

Specifying Plastering.

All joints should be raked out to a depth of $\frac{3}{4}''$ and walls should be washed and thoroughly wetted for three hours before the plastering is commenced. A rendering of plaster made of one lime to $\frac{1}{2}$ sand and stored for three days at least, sufficiently thick to cover by $\frac{1}{4}''$ all projections and walls, should be applied in an even and uniform coat and should be well beaten with hand tappers; freshly mixed lime mortar should not be used. Before applying the second coat, the first should be allowed to set, but not to become dry; it should also be well roughened. The finishing coat when white washing is not to be done should consist of a very fine thin coating of shell lime which will not be applied till the plaster is dried. This coat should be smoothed with a wooden rubber and polished with a trowel, lime water being sprinkled on it as required, the plastering and the polishing should be completed on the same day to prevent the hardening of the plaster. When a wall has to be whitewashed the plaster may be left rough unless otherwise instructed.

Grouting.

Grouting is very thin liquid mortar sometimes poured over courses of masonry or brick-work in order that it may penetrate into empty joints left in consequence of bad workmanship. It may also be necessary in deep and narrow joints between large stones. Grouting is, however, not approved of by all engineers. Grout itself is weak compared to good stiff mortar, and should not be used where it can be avoided.

Pointing.

Pointing should if possible be done whilst the mortar in the joints is fresh. The original mortar should be raked out to a depth of $\frac{3}{4}''$. The dust should then be brushed out of the joints and the work well wetted and washed with water. In lime pointing, the pointing mortar should be fine and should be composed of lime, sand and surkhi in the ratio of $1:1:\frac{1}{2}$. In the case of flush pointing, the procedure to be adopted is the same as in the above

except that the joint will be flat and flush with the surface of the brick-work. In cement pointing the ratio should be one of cement to one of sand; cement pointing should be executed as rapidly as possible and must not be again touched till it has begun to set. The joints of pointed work should be neatly defined by the pointing and the lines should be regular and uniform in breadth and the joints should be raised or flat as desired. After pointing, the work should be kept constantly wet for about six days.

Whitewash.

The walls should be thoroughly cleaned down and freed from all foreign matter before the whitewash is applied. In all cases, remove the old whitewash, and scrape the walls. The wash should be prepared from fresh burnt white limestone or shell lime. The slaked lime will be placed in tubs nearly full of water, and will then be mixed and stirred up with a pole until it attains about the consistency of cream, so thick that it does not readily drop from the brush. When sufficiently mixed, the wash will be taken out in small quantities and strained through a coarse cloth into earthen pots. Gum in the proportion of 2 oz to one cubic foot of lime should be added to the strained whitewash. Whitewash should be laid on in three coats with English brushes, the coats being laid on vertically and horizontally alternately. This applies to all colour washing, the only difference being that the colour specified or directed will be obtained by adding the necessary colouring matter, such as ground burnt cocoanut shells, yellow or red ochre to the white wash. The following is a good recipe for superior whitewash. White lime: 40 seers, slaked with hot water in a covered vessel. Salt 5 seers, dissolved in hot water. Coarse rice: 3 seers, pounded and boiled to a thick paste (kanji). Glue ½ seer, dissolved in hot water and the dirty refuse rejected. These ingredients should be mixed, stirred and diluted with hot water, till the consistency becomes that of ordinary whitewash. The mixture should then be allowed to simmer for a few hours over a fire; it should next be strained, and finally laid on to walls while hot. As the practice in this Presidency is to mix lime, salt and rice by measure and not by weight, the equivalents of above proportions by measure are half parah or 1·56 cubic feet of white lime, two Madras measures of salt, one Madras measure of rice and nine and a half palams of glue.

Specifying Painting.

All paints should be in the form of powder paste ground in oil or ready mixed as desired. Linseed oil should be raw or boiled according to the nature of the work. The raw oil should be limpid, pale, brilliant, mellow and sweet to the taste and with very little smell. Raw linseed oil to be used for the inside work. Driers to be litharge, sugar of lead, red lead or Japan varnish, as desired. New woodwork: Before painting, the wooden surfaces should be well washed with soap dissolved in water. The washing should be done by means of large whitewash brushes. After soap and water have been used, the surface should be well washed down with clean water and painters' hands must on no account touch the surface; the surface must be dry before the application of paint. All projections, tool marks and other irregularities should be smoothed off and all heads of screws and nails punched to ⅛″ below the surface. All knots should be filled with one or more coats of oil and white lead or red lead and size, or glue laid on warm and rubbed down with sand paper or pumice stone. After all the above have been gone through the priming coat should be applied with no turpentine thereon. After the priming coat has dried, all nail and screw holes or other irregularities should be filled with putty prepared as described below, and the required number of coats of paints should be applied as thinly and evenly as possible; all coats except the final one should be rubbed down with sand paper before the application of succeeding coat. In the case of old woodwork, the work should be thoroughly scraped and all the old paint should be removed. Old paint may be removed by burning with an ordinary painters' blow lamp or by covering the surface with kerosine oil or other paint remover and then burning; afterwards the paint may be scraped off. When old paint has been removed, the surface should be thoroughly cleaned from rust and dirt. Red lead alone should be used for priming. Before iron work is painted, the surface should be thoroughly cleaned from dirt and rust and red lead alone should be used for priming. Before painting on plaster, the surface should be quite dry and hard. The first coat should be thin and should consist of white lead with raw linseed oil and a small quantity of litharge. The second coat also should be thin so that the plaster may be thoroughly saturated. The third coat should be thicker and should contain a small quantity of turpentine with some of the required colouring pigment. The fourth coat also should be thick, having equal parts of linseed oil and turpentine. The fifth or floating coat to be of pure white lead with pigment to the required tint and diluted with spirits of turpentine.

BUILDINGS: THE METHODS OF VENTILATION APPLICABLE TO INDIAN CONDITIONS.

Ventilation.

If pure water is considered an essential requirement for health, pure air is as equally essential to health, as pure water. If we examine the huts and houses of the poorer classes, we will notice that no attempt has ever been made to provide for ventilation for the reason that they are ignorant of the fact that pure air is an essential requirement for health conditions. The head-aches and feelings of depression which follow the inhalation of impure air serve as warning notes of evils of want of pure air. Most of the poorer classes in this Presidency live in houses almost hermetically sealed against the entrance of fresh or the exit of foul air. They seem to possess an unfortunate immunity from indications of ill health due to inhalation of air loaded with impurities. The fact is that Nature ceases to sound its warning notes to such men who persist in disregarding them. It should be our endeavour to educate them in the matter of the necessity of pure air. In the case of water, a turbid appearance indicates the presence of impurity, while the air of our rooms however impure it may become by over-crowding, presents no visible evidence of this fact. There are a number of diseases produced by impure air. In addition to this, there are the following broad undeniable facts which prove the importance of fresh air. (1) By atmospheric impurity, the risk of infection and the severity of infectious diseases are greatly increased. A general lowering of the vital functions which renders illness more frequent and recovery more uncertain and prolonged results. (2) Fresh air is a chief factor which contributes to the earlier recovery of the patients in Hospitals which are well and satisfactorily ventilated than the patients in over-crowded and badly ventilated cottages. By ventilation is meant the dilution and removal of all impurities which collect in the air of inhabited rooms. When the ventilation is the result of forces, constantly acting in Nature, it is called 'Natural Ventilation.' When it is the result of forces set in action by man, it is called 'Artificial Ventilation.' Natural ventilation: Good ventilation is secured when the quantity of air required is supplied without any perceptible draught. Considerable cubic space is needed to secure this end. The change of air of a room from 3 to 4 times in an hour is considered in practice a maximum, if much draught is not to be created. In Public buildings, it has been found in practice that an air space of 1000 c ft. per head ensures best results in the matter of ventilation. A larger cubic space is seemingly unnecessary as it encourages stagnation of air. The advantage secured by a large space is that in case of temporary failure of wind or other means of ventilation, it affords a reserve of air and becomes vitiated less rapidly than a small space. Comparing large and small rooms in the matter of ventilation, it may be stated that large rooms are more easily ventilated than small rooms and small rooms require more numerous ventilating apertures and a provision of a larger cubic space per head. In calculating the cubic space for ventilation purposes, it is not usual to take into account the vertical spaces above the first twelve or fourteen feet For it may be stated, as a general rule, that the superficial area in square measurement is not less than 1/12 of the cubic space in cubic measurements. For Indian conditions where the roofs of buildings are strongly heated by the sun, it is an advantage to make the buildings high, so that the rooms may be cool. Large superficial space affords the rapid diffusion of the exhalations from lungs and skins of individuals and is therefore very useful in isolating individuals. Without producing draught 500 c. ft. per head is considered the smallest amount of cubic space that should be provided for to ensure purity of air in a dwelling room. per head is regarded as the smallest superficial space allowable in a dwelling room. A good allowance is 100 sq. feet per head and this floor area should invariably be provided in the ward pavilions of Hospitals. For the conditions in India, we have to depend upon the wind for natural ventilation. Tubes, shafts, etc., are unnecessary for Indian conditions. Simple and direct methods of ventilation e all that are necessary rooms with moderate heights, the simplest and most effectual method of ventilation is to provide a sufficient number of doors and windows. A good rule is to provide 1 square foot of opening for every 60 cubic feet of space in a room. Ventilation is best secured when doors and windows are opposite each other, as in fig. 20 in plate 16. The next best arrangement is windows in adjacent walls as in fig. 21 in plate 16. The worst case is when only one side of a room is open to the air outside as in fig. 22 in plate 16. Every room should have at least one side open to the atmosphere outside and even the smallest room should have at least one window in

addition to the door, as the door may have to be kept closed at nights. When the height exceeds 12 feet, it is to have openings near the ceiling or in the roof, as otherwise the hot impure air will accumulate in the space between the tops of windows and the ceiling. Ventilators in the side walls should as far as possible be open to the air as shown in fig. 19 in plate 16, and not under verandahs as shown in fig. 18 in plate 16. These openings are provided either with revolving shutters or fixed shutters. The latter are preferable as they always remain open. Indian houses are badly ventilated but they are not as bad as it would appear at first sight. The rooms are, as a rule, arranged round a court-yard which acts as a ventilating shaft. Ventilators can also be provided in the roofs of buildings. With terraced roofs, the simplest plan is to insert a 9" o 2" pipe through the terrace filled with a cover and wire gauge round the openings. With Mangalore tiles, special ventilating tiles are used. With tiled roofs, ridge ventilation is also possible. All kitchens should have a flue or roof ventilator for the escape of smoke. Latrines should have ridge ventilation as shown in figs. 23 and 24 in plate 16.

BUILDINGS: MAIN DETAILS OF CONSTRUCTION OF LATRINES AND URINALS AS GAINED FROM A STUDY OF PLANS.

Classification.

Latrines are usually divided into two classes, *viz.*, latrines on the conservancy system and latrines on the water carriage system. In the former system, the night-soil is retained in pans or pits and conveyed in night-soil carts, while in the latter system, the night-soil is removed by means of a flow of water and conveyed by a system of underground pipes. Latrines on the water carriage system can be used in towns provided with closed sewerage schemes. The latrines on the conservancy system are employed in all towns and villages in which the removal of night-soil is done by manual labour. Public Latrines, Private Latrines, Public Urinals, Private Urinals and Village Latrines and Temporary Latrines for fairs and festivals are the classifications, judged from their situations and purposes. The fact that the last say has not yet been said as regards the design of a latrine suitable to satisfy sanitary requirements and Indian habits is evidence that the question is complicated with a number of considerations, *viz.*, principles of design, habits of the users, general drainage systems, etc. In the first place, it will be admitted that the trouble in India is not chiefly due to the faulty character of the designs of latrines but is mainly due to the habits of the people to use the surroundings of a latrine instead of the latrine proper. There is no doubt that the water carriage latrines discharging the excreta and urine in a liquified form straight into closed sewers are the best and sanitarily perfect. It will be many decades of years before towns in this Presidency possess up-to-date closed sewerage schemes. Till then, we must be satisfied with the present make-shift methods of the conservancy system.

Proposals For Latrines.

All proposals for latrines should be accompanied by the following plans, estimates and report. "1. Site-plan—scale 330 feet=1 inch—(village-map or town survey) showing (i) position of work and surroundings for a distance of 1,000 feet from the site; also buildings, roads and wells and other sources of water-supply within this radius. Indicate those sources employed for (*a*) human consumption, (*b*) domestic purposes, (*c*) irrigation; (ii) the general trend of the ground by means of arrows; (iii) the position of latrines (if any) to be superseded; (iv) the source whence the ablution water is to be obtained if within the radius of the site plan. 2. Describe the soil and subsoil of the site, and give a section of a trial-pit. 3. If any of the inhabitants have objected to the site, forward a statement of their objections. 4. A statement showing the number of persons—(i) male, (ii) female, to be accommodated; (iii) the population (approximately) of the area within half a mile radius of the latrine; (iv) the distance of the nearest public latrine from the site selected. 5. The arrangements proposed for obtaining ablution water. 6. The manner in which the ablution water is to be conveyed to the latrine, and in which it is to be delivered there to the user of the latrine. 7. Proposed method of removal of fæcal matter and urine and washings, respectively, and the plant actually available for this purpose. 8. Proposed method of ultimate disposal of fæcal matter and urine and washings, respectively. 9. Describe in detail the nature of the surface or receptacle in which (i) the fæcal matter, and (ii) the urine is to be received. 10. If fæces and urine are received in different manners, describe each fully. 11. If deodorisation is intended, state (i) the material to be employed; (ii) the facilities for obtaining it; (iii) the probable cost. 12. If any apparatus is used for distribution of the deodorant, describe its action. 13. The accommodation, if any, on the spot for the toty attendant during hours of duty. 14. Give reasons for preferring the materials of which the structure is to be built, and state what alternative materials are available locally and their cost. 15. Detailed estimates and specifications of work to be done. 16. Plans and sections to be on a scale of 6 feet=1 inch. Copies of type-designs need not be sent up but the number of design should invariably be quoted."

Latrine Of 18 Seats: Plates 17 And 18.

In the above plates, is illustrated the type design No. 112-B issued with proceedings of the Madras Sanitary Board, No. 338-S., dated 29-9-11. The specification report which accompanied this design was as follows: General: The latrine will have 18 seats with corrugated iron partitions 2′ 3″ × 4′ 0″ between each seat with entrances on both sides of the latrine. The disposition of the seats, entrance, partitions, etc., and the arrangements of the seats, latrine pans, etc., should be as shown in the design. Foundations will be 2 feet deep in the case of walls of three sides of the latrine and for T iron pillars, 1′ 3″

for the rear wall of the latrine and for the retaining walls of the latrine seats. The whole depth of the foundations will be built of brickwork in surkhi mortar or if preferred the bottom 18" may be of concrete. The depth of the foundations will vary according to the nature of the soil on which the latrine is to be built and should be increased if local conditions of site require this to be done. If random rubble in surkhi mortar is cheaper than brickwork the foundation may be built of the former, or of concrete. Basement will be 1′ 6" high of brickwork in surkhi mortar. In places where stonework is cheaper than brickwork the basement may be built of coursed rubble first sort in surkhi mortar. The filling in of the basement should be with sand. Superstructure will be of 22 B. W. G. corrugated iron walls and T iron pillars supported by angle iron stiffeners. The height of the walls and the arrangements of the roof fastenings, etc., should be as shown in the design. Flooring will be of smooth Cuddapah slabs $1\frac{1}{2}$" thick laid on 4" of surkhi concrete and all joints shall be pointed to the full depth of the slab with best quality Portland cement. Roofing will be of 22 B. W. G. corrugated iron roofing on $1\frac{1}{2}" \times 1\frac{1}{2}" \times \frac{1}{4}"$ angle iron purlins over $2" \times 2" \times \frac{1}{4}"$ T iron rafters. The arrangements and fastenings, etc., of the roof should be as shown in the design. Finials: There will be two iron finials, one at each end of the roof. Filter trenches: There will be two filter trenches at each end of the latrine or behind the latrine if preferred, $15' \times 2'$ by 3' deep. The bottom 2 feet will be filled in with broken stone $\frac{3}{4}$" to $1\frac{1}{2}$" in size and the remaining 1 foot will be filled in with coarse sand. The whole trench will be sloped to a gradient of 1 in 30 away from the latrine as shown in the design. Pans: One iron pan will be provided for each seat and the position of the pans should be as shown in the design. Painting and tarring: The corrugated sheets and other iron work should be painted after erection with two coats of chocolate paint except the bottom 2 feet of sheets which may be painted with black paint. This painting should be renewed every two years. The pans should be tarred when first made and the tarring should be renewed every three months. Drainage: All the sullage water and the washings of the latrine should be carried away by drains built along the rear wall of the latrine and by the drain inside the latrine to the filter trenches located at each end of the latrine or behind the latrine, if preferred. Estimated cost: The estimated cost varies from Rs. 1,100 to Rs. 1,600. General: The design for 18 seats was drawn up for Erode Municipality. Messrs. T. A. Ponnu & Co., Madras, have quoted Rs. 810 for all iron work of this design delivered at Erode. The number of seats of the latrine may be decreased to suit local requirements.

Abstract Of Quantities For A Latrine Of 18 Seats: Plates 17 And 18.

Quantity.		Description of work.
663 c. ft.	...	Earthwork, excavating foundations.
203 „	...	Filling in basement with clean sand.
53 „	...	Concrete, broken stone in surkhi mortar.
693 „	...	Brickwork in surkhi mortar.
546 sq. ft.	...	Plastering with cement, $\frac{3}{4}$" thick.
200 „	...	Flooring with $1\frac{1}{2}$" Cuddapah slabs on 4" concrete including pointing with cement to the full depth of slab.
64 „	...	Flooring with $1\frac{1}{2}$" Cuddapah slabs and pointed with cement.
47 „	...	Cuddapah slab, $1\frac{1}{2}$" thick.
120 c. ft.	...	Broken stone from $\frac{3}{4}$" to $1\frac{1}{2}$" for filter trench.
No. 1	...	Latrine of 18 seats with corrugated iron walling, roofing with T iron rafters, L iron reepers, buckets, finials, etc., complete.
		Erecting latrine.
2,584 sq. ft.	...	Painting corrugated iron sheets on either sides.
		Sundries.
		Total Rs. ...

A Cheap Open Corrugated Iron Latrine Of 6 Seats: Plates 19 And 20.

In the above plates, is illustrated the type design No. 149 issued with proceedings of the Madras Sanitary Board, No. 55-S., dated 24 1-1914. The specification report which accompanied this design was as follows: General: The latrine will be in two compartments of three seats each with corrugated iron partitions 2′ 3" × 4′ 0" between each seat having an entrance in front for each compartment. The dispositions of the compartments, seats, partitions and steps shall be as shown in the design. Foundations will be brickwork in chunam, two feet deep in the case of all walls and concrete, broken brick in chunam, 2 feet deep in the case of the space enclosed within the retaining walls of seats. Stone or concrete may be used for foundation if this is found to be cheaper and advisable. The depth of the foundations will vary according to the nature of the soil. Basement will be brickwork in chunam 1 foot 6 inches high. Stone may be used for the basement if that is found to be cheaper. The filling in of the basement should be with the excavated earth. Superstructure will be of 20 B. W. G. galvanized corrugated iron sheets and $2" \times 2" \times \frac{1}{4}"$ angle iron pillars fixed on stone slabs $6" \times 6" \times 4"$ and supported by $1\frac{1}{2}" \times 1\frac{1}{2}"$ angle iron stiffeners. The height of the walling, the division into compartments together with the partitions of seats, should be as shown

in the design. Flooring will be of Cuddapah slabs 1½ inches thick laid over a levelling course of 4 inches concrete, broken brick in chunam with a slope of 1 in 10 towards the trench and all joints shall be pointed with the best quality Portland cement to the full depth of the slab. Seats: The space between the retaining walls of the seats above foundations will be filled in with concrete, broken brick in chunam and the liquid receiver rounded as shown in the section. For each seat a Cuddapah slab 2 feet 3 inches long and 10 inches wide will be imbedded in the concrete with a slope of 1 in 4 also towards the trench and the concrete sides shall be carefully rounded off with best Portland cement as shown in the design. Raised stone slabs 11" × 4" in cement shall be provided to serve as foot-rests. Plastering will be half an inch thick with best Portland cement mortar 3 to 1 to all surfaces of brickwork in basement. Trench: In rear of the seats there will be a trench 13 feet by 2 feet and 1 foot deep with a suitable embankment on its three sides and filled with sand as shown in the design. The object of sand in the trench is for the efficient filtration of sullage water. The sand which is considered to be the best as well as the cheapest filtering medium should be periodically renewed when it is seen to be choked which will be evident when the sullage water does not soak beneath the surface of the sand. Painting: All iron work shall be painted with two coats inside and outside of good zinc or lead paint chocolate colour. Upkeep of latrine: The liquid will run on to the trench and soak into the sand bed provided for the purpose. The solid excreta will be daily removed by a sweeper who will use a mamooty for that purpose and at the end of the operation will sprinkle sand in each compartment. Cost: The cost of latrine shown on the drawings will vary from Rs. 280 to Rs. 420 or cost of each unit will vary from Rs. 47 to Rs. 70.

Abstract Of Quantities For A Cheap Open Corrugated Iron Latrine Of 6 Seats: Plates 19 And 20.

Quantity.	Description of work.
249 c. ft. ...	Earthwork, excavation and filling in basement.
33 „ ...	Concrete, broken vitrified bricks in chunam.
199 „ ...	Brickwork, third sort, in chunam in foundation and basement.
119 sq. ft. ...	Plastering with cement ½" thick, 1 : 3.
104 „ ...	Flooring with Cuddapah slabs 1½" thick without concrete and pointing with cement to the full depth of the slab.
12 No. ...	Cuddapah slab foot-rests including setting, etc.
26 c. ft. ...	Sand-filling.
	Forming bund with excavated earth.
15 No. ...	Cutstone slabs under posts.
	Walling with 20 B.W.G. galvanized iron sheets (corrugated) with angles 1½" × 1½"×¼" battens and 2"×2"×¼" posts including rivets, etc., complete.
687 sq. ft. ...	Painting, two coats with lead paint.
	Sundries.
	Total Rs. ...

A House Latrine Of One Seat: Plate 21.

In the above plate, is illustrated the type design No. 101 issued with proceedings of the Madras Sanitary Board, No. 150-S., dated 30-4-1907. The specification report which accompanied this design was as follows: Amount of estimate, Rs. 14. General: The design is for a single seat house latrine for a native house. The latrine proper measures 2' 7"×2' 6". In front of the seat is the washing platform which measures 2' 7"×2' 0". It is not proposed to roof the latrine. 2. Foundations, basement and superstructure: Provision has been made for brickwork in clay. If rubble is cheaper than brickwork the work may all be done with the former material. 3. Flooring: The latrine seat consists of a cutstone specially cut as shown in plan. As regards the washing platform the flooring will be of 2" Cuddapah slabs laid on 4" chunam concrete and neatly pointed. 4. Inside and outside face of walls will be plastered with chunam, 2 coats, except for the first 2 feet from floor inside. The inside face of walls 2 feet high from floor should be plastered with cement. If the walls are of coursed rubble the face of the walls should not be plastered, but the joints should be neatly pointed with cement. 5. Door and lintel over door: These will be of country wood and of the dimensions detailed in the estimate. 6. Painting: The door and the lintel over it will be painted with tar 2 coats. 7. Drainage: The sullage water and the washings of the latrine should be carried away by drains as shown, and led on to street open drains or to a filter pit in a garden.

Abstract Of Quantities For A House Latrine Of One Seat: Plate 21.

Quantity.	Description of work.
48 c. ft. ...	Earthwork, excavation.
3 „ ...	Filling in with good earth.
7 „ ...	Concrete in chunam.

Quantity.		Description of work.
144 c. ft.	...	Brickwork in mud.
227 sq. ft.	...	Plastering with chunam, 2 coats.
54 „	...	Plastering with cement, ½" thick.
5 „	...	Flooring with 2" Cuddapah slabs over 4" chunam concrete and pointed.
6 „	...	Cuddapah slabs, 2" thick.
2·78 c. ft.	...	Cutstone work.
0·5 „	...	Country woodwork.
10 sq. ft.	...	Door (2' × 4½') country wood with a single batten shutter including hooks, hinges, etc., complete.
1 No.	...	Iron pan complete.
11 sq. ft.	...	Tarring door and lintel over it.
		Petty charges.
		Total Rs.

Latrine For An Out-patient Dispensary: Plate 22.

In the above plate, is illustrated the type design No. 148-A issued with proceedings of the Madras Sanitary Board, No. 918-S., dated 19-12 1913. The specification report which accompanied this design was as follows: Foundations: A depth of 2 feet is provided, the lower 1 foot being concrete broken brick in lime mortar and the upper 1 foot being of brick in lime mortar. The required depth and width will be settled locally according to the nature of the soil. Walling: Construct the walls of ground moulded brick in lime mortar, in English bond according to the thickness shown upon the drawing Woodwork: The scantlings provided in the quantities for the timber throughout are suited to well seasoned Erool (*Xylia dolabriformis*) or Pillaimarudu (*Terminalia paniculata*). All timber should be free from shakes and other defects and sawn die square. Roofs: Cover the roofs with plain Mangalore tiles on teak reepers. Flooring: Pave the floors with 4 inches of concrete rendered with Portland cement ½" thick. Finishing: The whole of cistern in rear and the interior walls of latrine to a height of 3 feet from floor level to be rendered with Portland cement ½" thick. Cover the remaining portion of intérior walls and all the exterior walls with one coat of lime plaster and two coats of whitewash. All roof timbers will have two coats of tarring. Cost: The building shown upon the drawing is estimated to cost from Rs. 350 to Rs. 525 according to locality.

Abstract Of Quantities For A Latrine for An Out-patient Dispensary: Plate 22.

Quantity.		Description of work.
369 c. ft.	...	Excavation for foundations.
19 „	...	Filling in basement with earth.
167 „	...	Concrete, broken brick in lime mortar.
119 „	...	Brick in lime mortar, foundations.
514 „	...	Brick in lime mortar, superstructure.
74 sq. ft.	...	Honey-comb tiled work.
15 r. ft.	..	Brick cornice work including finishing.
9·93 c. ft.	...	Timber, wrought and put up.
221 sq. ft.	...	Roofing with plain Mangalore tiles including teak reepers complete.
93 sq. ft.	...	Levelling course of concrete 4" thick.
93 sq. ft.	...	Rendering with Portland cement ½" thick.
678 sq. ft.	...	Plastering with lime mortar, one coat including two-coats of whitewash.
285 „	...	Rendering with Portland cement ½" thick.
L. S.		Tarring rafters and wall plates.
15 r. ft.	...	Masonry drain in rear of latrine, leading water to cistern in rear, including finishing.
No. 1.	...	Wooden trap door for cistern.
No. 1.	...	Iron bucket.
No. 4.	...	Iron pans.
No. 1.	...	Iron tube in wall of cistern.
		Petty supervision at 2½ per cent.
		Contingencies at 5 per cent.
		Total Rs.

A Conservancy Latrine: Plates 23 And 24.

In the above plates, is illustrated the design for a Conservancy Latrine issued by the Government of Madras. The specification report which accompanied this design was as follows: General: The latrine will be in two parts of eight seats each; one part will be for males and the other part for females. There will be four entrances to the latrines, two for each part. The general idea of the latrine is a masonry structure supporting a floor at a height of four feet above ground. The floor of the latrine is proposed of a stone slab or reinforced concrete slab according to the local material available. Each seat is provided with the usual partition walls, the space available between them being 2' 3". In the slab floor there will be a hole 14" long and 9" wide. The two parts of the latrine are built back to back with a conservancy passage six feet wide between them, and a suitable screen wall at each end to hide the view of the latrine from passers-by. The principle of the latrine is as follows. The position of the stone slab for the floorings with a sufficiently large hole 14" × 9" will result in the interior of the latrine being kept perfectly clean and unobjectionable. All liquids and solids will be passed through the hole in the floor and will fall on a small heap of sand at ground level underneath these seats. The liquid will soak into the sand and will usually evaporate and the

solids will be removed daily by means of a mamooty and a basket, and a conservancy cart will pass through the six feet passage between the latrines. The only periodical requirement of the latrine will be a supply of fresh sand which can be thrown in the space under each seat. Where fresh sand is not available then dry earth can be used with advantage. In designing the latrine, the object in view is to attempt to design a latrine which each user would find clean and unobjectionable despite the inattention of the conservancy staff which is usually evident at present with latrines in which pans are provided. The principle is a reversion to the old style of closet which was used in England within the last thirty years and is still used in out of the way places. Foundation: The foundation will be 2′ 6″ deep composed of broken stone or brick in chunam. Between the concrete and ground level the walls will be built of brick in mud. The depth of the foundation will vary according to the nature of the soil, but in ordinary situations the depth, *viz.*, 2′ 6″ would be ample. Basement: The basement will be 3′ 8″ high built of brick in mud. The filling in of the basement will be of dry earth or sand as locally available. Superstructure: The superstructure will be of 9″ walls of brick in mud. The partition between each seat will be 4½″ thick, also of brick in mud. Flooring: The floor of the latrine will consist of stone slabs, 4″ thick provided with a hole in the position shown, measuring 14″ × 9″. The slight depression in the stone slab which will require to be cut out will act as a drain when the floor of the latrine is rinsed with water for occasional cleansing. In places where stone slabs are not available, reinforced concrete slabs made with expanded metal, broken stone ¾″ gauge and cement mortar will be used instead. These slabs can be made on the ground and lifted into place as in the case of stone slabs. Access: The access to the latrine should be provided at each end, that is to say, there will be two entrances to each part, two for males and two for females. The inside surface of the latrine shall be plastered with cement mortar and the outside surfaces shall be plastered with chunam mortar as provided in the schedule of quantities. Screen wall: The two parts of the latrine each consisting of eight seats shall be built six feet apart, this space forming a conservancy passage and at end of the passage there shall be a screen wall in the position shown. Cleaning of the latrine: The latrine shall be cleansed as described under paragraph "General" above and the floor shall be occasionally washed out with water. The washings from the floor will escape by the drain shown in the plan to a small filter well where they will soak into the ground. Cost of the latrine: At Madras rates the latrine is estimated to cost Rs. 1,020 or at the rate of Rs. 64 per seat.

Abstract Of Quantities For A Conservancy Latrine: Plates 23 And 24.

Quantity.		Description of work.
531 c. ft.	...	Earthwork, excavation.
644 "	...	Concrete, broken bricks in chunam.
660 "	...	Brick masonry in chunam in foundation.
956 "	...	Brick masonry in chunam in basement.
789 "	...	Brick masonry in mud in superstructure
587 sq. ft.	...	Plastering with cement, ½ inch thick, 1:3.
2,773 "	...	Do. chunam, 1 coat.
391 "	...	Four inch stone flooring and pointing with cement.
Sum	...	Connecting pipe, etc.
Sum	...	Making holes and forming drains in stone slabs.
Sum	...	Filling in with broken bricks, etc., in filter well.
...		Sundries.
		Total Rs.

Corrugated Iron Latrines: Plates 25 to 28.

In the above plates are illustrated two designs of latrines issued by Mr. W. Hutton, Sanitary Engineer to the Government of Madras for certain local bodies in the Presidency of Madras. The specification report which accompanied this design was as follows: 1. Design: The designs show two alternative types as follows: A. Single Type, with roof (plates 25 and 26). B. Double Type with roof (plates 27 and 28). The single type is intended for use by one sex of people only, and the double type by both the sexes. 2. General arrangement: The single type latrine shows 18 seats arranged in a single row; the double type is divided into two compartments of 9 seats each by a partition wall 6 feet high. Each seat will be separated from the other by a partition wall 3′ 9″ high provided with also a half door 3 feet high in front of each seat to secure privacy. The disposition of the seats, entrances, partitions, &c., will be as shown in the designs. 3. Foundations will be 2 feet deep in the case of walls on the three sides of the latrines as well as for T iron pillars; and 1′-3″ for the rear walls of the latrines and for the retaining walls. The whole depth of the foundations will be built of brickwork in surkhi mortar or if preferred the bottom 18″ may be filled in with concrete. The depth of the foundations will vary according to the nature of the soil. If random rubble in surkhi mortar is cheaper than brickwork, the foundations may be built of the former. 4. Basement will be 1′ 6″ high of brickwork in surkhi mortar. In places where stone masonry is cheaper the basement may be built of coursed rubble, first sort, in surkhi mortar. 5. Filling in of basement will be with sand. 6. Walling will be of 22 B.W.G. corrugated iron sheets fixed to T and angle iron pillars and stiffened by angle

irons as shown on plans. A space of 3 inches should be left between the floor of the latrine and the bottom of the corrugated iron walling to admit of free circulation of air at the floor. 7. Flooring will be of Cuddapah slabs 1½" thick laid on a levelling course of 4" surkhi concrete and pointed with good Portland cement to the full depth of the slab. 8. Roofing will be of 22 B.W.G. corrugated iron sheets laid on T iron rafters supported by angle iron purlins. The other arrangements and fastenings, etc., of the roof are shown on the plans. There will be two iron finials one at each end of the roof. 9. Pans: One iron pan will be provided under each seat, as shown on the plans, in a recess formed to receive it. The pan is prevented from being pushed in too much by means of two vertical stops built in masonry. The pans should be tarred when first made and the tarring should be renewed every three months. The broken pans should be immediately replaced by new ones, and for this purpose a stock of spare pans should be kept and equal to about one-third the total number in use. 10. Filter Trench: There will be two filter trenches one at each end of the latrine as shown on the plans The filter trenches consist of a single row of 3" open jointed stoneware pipes surrounded by broken stones ¾" to 1½" in size. The length of 15 feet for each trench shown on the plans is expected to be found sufficient in ordinary porous soils such as sandy or gravelly. The length may, however, be increased to suit any particular soil as determined by trial. The trenches will not give satisfactory results in clay soil; in this case, two filter wells may be substituted, the same being carried down to porous soil below clay, provided the maximum subsoil water level is below the top of porous soil. In cases where either of the above methods is not practicable, the disposal of the sullage from the latrine should be arranged in consultation with the District Medical and Sanitary Officer, the Sanitary Commissioner and the Sanitary Engineer. 11. Painting: The corrugated iron sheets and other iron work should be painted after erection with two coats of chocolate paint except the bottom two feet of the sheets which may be painted with black paint. The painting should be renewed at least every two years. 12. Drainage: All the sullage water and the washings of the latrine will be carried away by the drains built along the rear wall of the latrine and along the front of the seats to the filter trenches located at each end of the latrine. 13. Estimated Cost: The estimated costs of the different latrines vary as follow according to the locality: (Plates 25 and 26) Single type with roof from Rs. 1,740 to 2,610. (Plates 27 and 28) Double Type with roof from Rs. 1,730 to 2,595. 14. Miscellaneous: (*a*) Number of seats to be provided: In Proceedings of the Sanitary Board No. 23/S dated 8th January 1915, the number of seats per thousand of population has been fixed at 32 in two latrines of 16 seats each (8 for males and 8 for females) in different localities. The number of seats may be fixed in accordance with the above. (*b*) General upkeep of latrine: In order to ensure satisfactory working, it is of utmost importance that the latrines should be cleaned and washed two to three times a day and for this purpose sufficient staff should be employed.

Abstract Of Quantities For A Corrugated Iron Latrine (Single Type) With Roof. Plates 25 and 26.

Quantity.		Description of work.
548 c. ft.	...	Earthwork, excavating foundation.
148 "	...	Filling in basement with clean sand.
62 "	...	Concrete, broken stone in surkhi mortar.
720 "	...	Brick in surkhi mortar.
605 sq. ft.	...	Plastering with cement, ¾" thick.
200 "	...	Flooring with 1½" Cuddapah slabs on 4" concrete including pointing with cement to the full depth of slab.
64 "	...	Flooring with 1½" Cuddapah slabs and pointed with cement.
47 "	...	Cuddapah slabs 1½" thick.
4·84 c. ft.	...	Cutstone work.
16 No.	...	3" stoneware pipes.
30 c. ft.	...	Broken stones, ¾" to 1½"
1 No.	...	Latrine of 18 seats with corrugated iron walling, roofing with T iron rafters L iron reepers and doorways in front of seats including pans, finials, etc., complete.
		Erecting latrine.
2845 sq. ft.	...	Painting corrugated iron sheets, both sides.
		Iron grating.
		Contingencies and petty supervision @ 7½%.
		Total Rs. ...

Abstract Of Quantities For A Corrugated Iron Latrine (Double Type) With Roof. Plates 27 and 28.

Quantity.		Description of work.
537 c. ft.	...	Earthwork, excavating foundation.
130 "	...	Filling in basement with clean sand.
65 "	...	Concrete, broken stone in surkhi mortar.
709 "	...	Brick in surkhi mortar.
560 sq. ft.	...	Plastering with cement ¾" thick.
190 "	...	Flooring with 1½" Cuddapah slabs on 4" concrete including pointing with cement to the full depth of slab.
64 "	...	Flooring with 1½" Cuddapah slabs and pointed with cement.

Quantity.	Description of work.
47 sq. ft. ...	Cuddapah slabs, 1½" thick.
4·84 c. ft. ...	Cutstone work.
16 No. ...	3" stoneware pipes.
30 c. ft. ...	Broken stones from ¾" to 1½".
1 No. ...	Latrine of 18 seats with corrugated iron walling, partition, roofing with T iron rafters, angle iron reepers including pans, etc., complete.
	Erecting latrine.
2823 sq. ft. ...	Painting corrugated iron sheets, both sides.
	Iron grating.
	Contingencies and petty supervision at 7½%
	Total Rs. ...

A Flush Latrine With Three Seats: Plate 29.

In the above plate is illustrated the type design No. 105 issued with proceedings of the Madras Sanitary Board, No. 145-S, dated 20-3-1909. The specification report which accompanied this design was as follows: 1. The design consists of (1) the latrine proper with three seats with corrugated iron partitions and a passage in front, (2) an elevated iron tank of twenty gallon capacity to flush the latrine, (3) a washing platform and (4) a syphon trap and a ventilating shaft in the outlet pipe. The dispositions of latrine, iron tank, platform, etc., and the arrangements of seats, drain, etc., should be as shown in the design. 2. Foundation and basement: The foundation of the retaining walls, etc., will be 2 feet deep, the bottom 9 inches of which will consist of surkhi stone concrete. The walls in foundation (above concrete) and in basement will be built with brick in surkhi mortar. In places where coursed rubble work is cheaper than brickwork, the former may be substituted for the latter. If the nature of soil is loose the depth of foundation should be increased. 3. Seats and flooring: The flooring will be with Cuddapah slabs laid on 4 inches of concrete and pointed with cement to the full depth of the slabs. Raised stone slabs, 12" × 5", set in cement are provided for foot rests. The slabs in each compartment will be in two blocks which are so laid as to have a ¾" slope towards centre, where there will be a chisel cut V drain leading towards the opening. The passage also will be sloped towards the seats. The urine receiver will be dished in the form of W. C. pan. 4. Drain below seats will be in the form of 9 inches open drain and will be built in concrete with a slope of 1 in 100, plastered with cement and covered with Cuddapah slabs as detailed above. 5. Superstructure and roofing will be of corrugated iron sheets fixed to angle iron posts, rafters, etc. The posts should be carried deep into the foundation in concrete. 6. Flush tank: A galvanized W.I. automatic flushing tank of 20 gallons capacity as per figure No. 266 on page 103 of Ham Baker's catalogue of January 1905, is provided to flush the latrine. It will be supported on angle iron horizontals which should be fixed to the angle iron posts around the washing platform. These posts will be of larger dimensions than others to bear the extra weight of the tank. The inlet pipe will be 1½ inches in size. 7. Washing platform will be 2′ 6″ × 2′ 1″ and consists of Cuddapah slabs on concrete and will be in two blocks sloping towards the centre and towards the opening into the drain below. There will be a tap in the platform, which will have connection with the inlet pipe of the tank. The branch pipe to the tap will be in the form of a syphon. 8. Syphon trap: The outlet from the latrine will be 6 inches stoneware pipe and will pass through 6 inches syphon trap and pipe into the nearest street sewer. If possible 9 inches syphon trap and pipe may be substituted for 6 inches ones. There will be a ventilating shaft fixed to the pipe leading from the syphon trap. 9. The estimated cost of the design varies from Rs. 400 to Rs. 600.

Abstract Of Quantities For A Flush Latrine With Three Seats: Plate 29.

Quantity.	Description of work.
147 c. ft.	Earthwork, excavating foundations.
89 "	Concrete, broken stone in surkhi mortar.
114 "	Brickwork in surkhi mortar.
L.S.	Archwork.
284 sq. ft.	Cement plastering, ½" thick.
27 "	Flooring with 2" Cuddapah slabs pointed with cement to the full depth of slab.
33 "	Flooring with 2" Cuddapah slabs on 4" concrete including pointing with cement to the full depth of slab.
L S.	Labour for making holes in Cuddapah slabs for seats and for pipes.
891 lbs.	Angle iron work.
256 sq. ft.	Corrugated iron sheets (20 B.W.G.) for walling, roofing with bolts, nuts and washers including hook bolts, etc., complete.
14 l. ft.	6" Stoneware pipes.
No. 1	6" Stoneware syphon pipe.
	6" × 4" stoneware branch.
	Sewer ventilating shaft, 4" internal diameter, with cast iron ground base with 1½" deep bolts and welded tube including coronet and copper wire cage as per No. 498, page 124 of Messrs. Ham Baker & Co.'s catalogue of 1905. Height out of ground 10 feet.
42 l. ft.	Supply and delivery of 1½" wrought iron galvanised tubes.
No. 3	1½" wrought iron galvanised couplings.

Quantity.		Description of work.
No. 2	...	$1\frac{1}{2}'' \times 1\frac{1}{2}''$ wrought iron galvanised knees or elbows.
" 1	...	$1\frac{1}{2}'' \times 1\frac{1}{2}'' \times 1\frac{1}{2}''$ branch.
" 1	...	$1\frac{1}{2}''$ wrought iron galvanised syphon pipe.
" 1	...	$1\frac{1}{2}''$ to 1" reducing coupling.
" 3	...	1" wrought iron galvanised bends.
" 1	...	$1\frac{1}{2}''$ stop cocks.
" 1	...	Wrought iron mouth pipe.
" 1	...	$\frac{1}{2}''$ discharge cock.
" 1	...	Messrs. Ham Baker's galvanised wrought iron "Municipal" automatic flush tank, 20 gallon capacity with vertical outlet and bend pipe complete.
	...	Laying and jointing pipes, stop cocks and jointing stoneware pipes and fixing ventilating shafts, etc.
	...	Petty charges.
		Total Rs. ...

Flush Out Latrine: Plate 30.

In the above plate is illustrated a design of a flush out latrine as designed by Mr. Madeley, Special Engineer, Corporation of Madras. This design was redrawn for the requirements of Local Bodies in the Presidency of Madras by Mr. W. Hutton, Sanitary Engineer to the Government of Madras and his specification report accompanying this design was as follows: 1. The design consists of (1) the latrine proper with three seats separated from each other by a 3" partition wall and open in front, (2) a passage 2' 6" wide in front of the seats with a door at one end for entrance, (3) a washing platform at the end of the latrine away from the entrance, with a tap, (4) an elevated automatic flush tank of 20 gallons capacity at one end of the latrine, inside, (5) ablution taps at each seat and (6) an intercepting trap at the end of the 6" S.W. pipe provided with an inspection chamber with cast iron light cover. 2. Foundations: A depth of 2' 6", is provided, the lower 12 inches being of broken stone in surkhi mortar and the upper 1' 6", brick in surkhi mortar. The depth and width of the foundations will be settled locally according to the nature of the soil. 3. Basement: Brick in surkhi mortar, six inches high. 4. Walling: Walls and cornice will be built of brick in surkhi mortar. 5. Seats and flooring will consist of cement plastering on concrete consisting of broken stone in surkhi mortar with a hole opening into the stoneware pipe line below. The flooring in each compartment will have a $\frac{3}{4}$ inch slope towards the centre; and the passage will be sloped towards the drain running against the outer wall. The urine receiver will be dished in the form of a water closet. 6. There will be a row of 6" S.W. pipes laid below the seats to lead off the contents of the closet and washings towards the intercepting trap. 7. Flush tank: A galvanised wrought iron automatic flush tank of 20 gallon capacity is provided to flush the S. W. pipe line below the seats. It will be supported by a wooden bracket fixed to the wall. 8. Washing platform will be of the form shown on the plan. The washings from the same first run into a silt catcher and thence into the stoneware pipe below. There will be a tap at the washing platform. 9. Intercepting trap and inspection chamber: The 6" S.W. pipe line ends in an inspection chamber, 2'×2', provided with a cast iron light cover from which the contents will pass through a 4" intercepting trap towards the street sewer or other disposal works. 10. Finishing: External and internal walls will be plastered with Portland cement, $\frac{1}{2}''$ thick. 11. Cost: The estimated cost of the design varies from Rs. 320 to Rs. 480. 12. Alternative arrangement for flushing: In this case the galvanised iron flush tank is omitted and a tipping bucket is provided near the washing platform. Into this bucket the spill water from the washing place will run. 13. The estimated cost of this arrangement varies from Rs. 310 to Rs. 465.

Abstract Of Quantities For A Flush Out Latrine: Plate 30.

Quantity.		Description of work.
		Flush out Latrine, with automatic flushing tank.
174 c. ft.	...	Earthwork, excavating foundations.
101 "	...	Concrete, broken brick in surkhi.
258 "	...	Brickwork in surkhi mortar.
629 sq. ft.	...	Plastering with cement, $\frac{1}{2}''$ thick.
43 "	...	Roofing with plain Mangalore tiles.
2·30 c. ft.	...	Teak timber, wrought and put up.
58 sq. ft.	...	Painting woodwork with Imperial zinc white.
1 No.	...	Teak wood self closing light door with frame, hinges, springs, etc., complete.
10 r. ft.	...	Zinc sheet gutter.
2 No.	...	Wrought iron gutter holders.
4 No.	...	6" stoneware pipes.
3 No.	...	6"×6" stoneware branches.
1 No.	...	Stoneware intercepting trap.
1 No.	...	Cast iron light cover with frames, etc., complete.
1 No.	...	Circular grating.
1 No.	...	4" stoneware silt trap including fixing.
2 No.	...	Teak wood bracket stand for flushing tank.
1 No.	...	Automatic flushing tank with flushing pipe, etc., complete.
Sum.	...	Wrought iron galvanized service pipe with taps, stopcocks including laying and jointing, etc., complete.
Sum.	...	Laying and jointing stoneware pipes.
Sum.	...	Forming drains, etc.
		Sundries.
		Total Rs. ...

Abstract Of Quantities For A Flush Out Latrine : Plate 30.

Quantity.	Description of work.
	Flush out Latrine, with tipping buckets.
197 c. ft.	... Earthwork, excavating foundations.
115 „	... Concrete, broken stone in surkhi.
267 „	... Brickwork in surkhi.
648 sq. ft.	... Plastering with cement, ½" thick.
43 „	... Roofing with plain Mangalore tiles.
2·30 c. ft.	... Teak timber, wrought and put up.
58 sq. ft.	... Painting woodwork with Imperial zinc white.
No. 1	... Teakwood self-closing door with frame, hinges, springs, etc., complete.
10 r. ft.	... Zinc sheet gutter.
No. 3	... Wrought iron gutter holders.
·No. 4	... 6" stoneware pipes.
No. 3	... 6" × 6" stoneware branches.
No. 1	... Stoneware intercepting trap.
No. 1	.. Cast iron light cover with frames, etc., complete.
No. 1	... Circular grating.
No. 1	... Tipping bucket.
No. 1	... 4" stoneware silt trap including fixing wrought iron galvanized pipe with taps, stop cocks including laying and jointing, etc., complete.
	Laying and jointing stoneware pipes, etc.
	Forming drains.
	Sundries ...
	Total Rs. ...

Flush Out Latrine: Plate 31.

In the above plate is illustrated a design of a flush out latrine as designed by Mr. Madeley, Special Engineer, Corporation of Madras. This design was redrawn for the requirements of Local Bodies in the Presidency of Madras by Mr. W. Hutton, Sanitary Engineer to the Government of Madras and his specification report accompanying this design was as follows: The design consists of (1) the latrine proper with three seats separated from each other by 3" ferro-concrete slab partition with an Indian closet basin or an English water closet basin with 3 gallons flush tank of the usual type above each basin, (2) a passage in front, (3) a self closing half-door in front of each seat, (4) an inspection chamber at the junction of the 4" S W pipe line conveying washings from the closets and 4" open drain in the passage respectively, (5) a ventilating shaft connecting with the inspection chamber. 2. Foundations: A depth of 3 feet 6 inches is provided, the lower 12 inches being concrete of broken stone in surkhi mortar and the upper 2 feet 6 inches, brick in surkhi mortar. The depth and width of foundations will be settled locally according to the nature of the soil. 3. Basement: Brick in surkhi mortar, 6 inches high. 4. Walling: Walls and cornice will be built of brick in surkhi mortar. 5. Stone work: The lintels over connection pipe of basins will be provided with cutstone. 6. Woodwork: One of the timbers mentioned in Circular No. 2040-C., dated 27th April 1909 as applicable to Table I of Circular No. 234-C, dated 9th January 1908 should be used. 7. Door: Teak wood self closing flap door with two leaves is fixed with a clearance of 12 inches from the floor. 8. Roofing will be covered with plain Mangalore tiles. At the eave end, the roof is provided with a wrought iron gutter. 9. Flooring will be of concrete rendered with Portland cement, ½" thick. 10. Finishing: External and internal walls will be plastered with Portland cement, ½ inch thick. 11. Flushing tank: 3 gallons syphon flushing tank with chain and handle to work it by the user of the seats is provided in each compartment and it is supported on teak brackets. 12. Cost: The estimated cost of the design varies from (1) when it is provided with English water closet Rs. 650 to Rs. 975, (2) when it is provided with Indian water closet Rs. 630 to Rs. 945.

Abstract Of Quantities For A Flush Out Latrine: Plate 31.

Quantity.	Description of work.
288 c. ft.	Earthwork, excavation.
141 „	Concrete, broken stone in surkhi mortar.
376 „	Brickwork in surkhi.
4 „	Archwork.
1 „	Cutstone lintels.
740 sq. ft.	Plastering with cement, ½" thick.
3·47 c. ft.	Teakwood, wrought and put up.
61 sq ft.	Roofing with plain Mangalore tiles including teak reepers.
11 r. ft.	Zinc sheet gutter.
No. 3	Teakwood bracket stand for syphon flushing tank including painting, fixing, etc.
No. 3	European Water closets including fixing.
No. 3	Syphon flushing tanks with flushing pipe, chain including fixing.
No. 3	Wrought iron gutter holders.
No. 11	4" stoneware pipes.
No. 3	4" „ slant branches.
No. 3	4" „ right angle branches.
No. 4	4" „ ½ bends.
No. 3	4" „ ¼ bends.
No. 1	4" „ silt trap.
Sum	Laying and jointing stoneware pipes, etc.
No. 1	Cast iron cover over silt trap including fixing.
No. 1	Cast iron light cover with frame, clear opening 24"×24", including fixing, etc., complete.
No. 3	Teakwood self closing door including frame, springe hinges, etc., complete.

Quantity.		Description of work.
No. 1	...	Ventilating shaft, 20' out of ground, with cast iron ground base welded tube including clamps, fixing, etc.
Sum	...	Wrought iron galvanized service pipe including stopcocks, fittings, laying, and jointing, etc , complete.
116 sq. ft.	...	Painting, 2 coats with Imperial zinc white.
		Sundries ... ...
		Total Rs ...

Flush Out Latrine: Plate 32.

In the above plate is illustrated a design for a flush out latrine as designed by Mr. Hutton, Sanitary Engineer to the Government of Madras based on Mr. Madeley's design shown on plate 30. The specification report accompanying this design was as follows: The design consists of (1) the latrine proper with three seats separated from each other by a $4\frac{1}{2}''$ partition wall and provided with a $9''$ screen in front of each seat. In lieu of the screen, self-closing half-doors may be provided, (2) a passage 3' wide in front of the seats, (3) a washing platform at the entrance with a tap, (4) an elevated automatic flush tank of 20 gallons capacity, (5) ablution taps at each seat, and (6) an intercepting trap at the end of the stoneware pipe provided with the usual inspection chamber and ventilating shaft. 2. Foundations: A depth of 2 feet 6 inches is provided, the lower 12 inches being concrete of broken stone in surkhi mortar, and the upper 1 foot 6 inches, brick in surkhi mortar. The depth and width of foundations will be settled locally according to the nature of the soil. 3. Basement: Brick in surkhi mortar, 6 inches high. 4. Walling: Walls and cornice will be built of brick in surkhi mortar; and $9''$ corrugated iron screen with angle iron frames is provided in front of seat. A clearance of $3''$ is given from the floor to the bottom of screen. 5. Seats and flooring will consist of cement plastering on concrete consisting of broken stone in surkhi mortar with a hole opening into the S.W. pipe line below. The flooring in each compartment will have a $\frac{3}{4}''$ slope towards the centre, and the passage also will be sloped towards the seats. The receiver will be dished in the form of a water closet. 6. There will be a row of 2 stoneware pipes laid below the seats to lead the contents of the closet and washings towards the intercepting trap. 7. Flush tank: A galvanized wrought iron automatic flush tank of 20 gallons capacity is provided to flush the stoneware pipe line below the seats. It will be supported partly on the walls and partly on a beam. The inlet pipe will be $1\frac{1}{2}''$ in size and outlet pipe $2\frac{1}{2}''$ in size. 8. Washing platform will be $3' \times 2'\text{-}7\frac{1}{2}''$. The washings from the same first run into a silt trap and thence into the stoneware pipe below. There will be a tap at the washing platform which will be connected to the inlet pipe of the tank. 9. Intercepting trap and inspection chamber: The $6''$ stoneware pipe line ends in an inspection chamber $2' \times 2'$ provided with a cast iron light cover; from which the contents will pass through a $4''$ intercepting trap towards the street sewer or other disposal works. There will also be a $4''$ ventilating shaft, 20' high above ground level, in order to prevent sewer gas entering the latrine through the intercepting trap. 10. Finishing: External and internal walls will be plastered with Portland cement, $\frac{1}{2}''$ thick. 11. Cost: The estimated cost of the design varies from Rs. 400 to Rs. 600. 12. Alternative arrangement for flushing: In this case the galvanized iron flush tank is omitted and a tipping bucket is provided by the side of the washing platform. Into this bucket the spill water from the washing place will run. The chamber of the tipping bucket is covered over with Cuddapah slab. 13. The estimated cost of this arrangement varies from Rs. 350 to Rs. 525.

Abstract Of Quantities For A Flush Out Latrine: Plate 32.

Quantity.		Description of work.
204 c. ft.	...	Earthwork, excavation.
126 "	...	Concrete, broken stone in surkhi.
277 "	...	Brickwork in surkhi mortar.
670 sq. ft.	...	Plastering with cement, $\frac{1}{2}''$ thick.
$8\frac{1}{2}$ "	...	Corrugated iron sheet screen with angle iron frames, etc., including fixing.
No. 2	...	$6''$ stoneware pipes.
No. 4	...	$4''$ do.
No. 3	...	$6''$ right branches.
No. 1	...	$4''$ slant branch.
No. 1	...	$4''$ intercepting trap.
No. 1	...	Cast iron circular grating.
No. 1	...	Cast iron manhole cover, clear opening $24''$, including fixing.
No. 2	...	Teakwood brackets including fixing, etc.
No. 1	...	Automatic flushing tank with cast iron flushing pipe including clamps, fixing, etc.
		Wrought iron galvanized service pipes with taps, stopcocks including laying, and jointing, etc., complete.
		Laying and jointing stoneware pipes, etc.
No. 1	...	$4''$ ventilating shaft with ground base (cast iron) welded tube, wire cage, wall clamp, fixing, etc., complete.
		Sundries ... .
		Total Rs. ...

Flush Out Latrine: Plate 33.

In the above plate is illustrated a design for a flush out latrine as designed by Mr. Hutton,

Sanitary Engineer to the Government of Madras based on Mr. Madeley's design shown on plate 31. The specification report accompanying this design was as follows: The design consists of (1) the latrine proper with three seats separated from each other by 3" ferro-concrete slab partition walls and each seat is provided with an Indian closet basin or English water closet basin with a 3 gallons flusk tank of the usual type above each basin, (2) a passage in front, (3) a self closing half-door in front of each seat, (4) an inspection chamber at the junction of the 4" S. W. pipe line conveying washings from the closets and 4" open drain in the passage respectively, (5) a ventilating shaft connecting with the upper end of the 4" S.W. pipe line. 2. Foundations: A depth of 3' 6" is provided, the lower 12" being concrete of broken brick in surkhi mortar and the upper 2' 6", brick in surkhi mortar. The depth and width of foundations will be settled locally according to the nature of the soil. 3. Basement: Brick in surkhi mortar, 6" high. 4. Walling: Wall and cornice will be built of brick in surkhi mortar. 5. Stone work: The lintels over connection pipe of basins will be provided with cutstone. 6. Woodwork: One of the timbers mentioned in Circular No. 2040-C dated 27th April 1909, as applicable to Table I of Circular No. 234-C dated 9th January 1908 should be used. 7. Door: Teak wood self closing flap door with two leaves is fixed with a clearance of 12" from floor. 8. Roofing will be with plain Mangalore tiles. At the eave end, the roof is provided with a wrought iron gutter. 9. Flooring will be of concrete rendered with Portland cement, ½" thick. 10. Finishing: External and internal walls will be plastered with Portland cement, ½" thick. 11. Flushing tank: 3 gallons syphon flushing tank with chain and handle to work it by the user of the seats is provided in each compartment, and it is supported on teak brackets. 12. Cost: The estimated cost of the design varies from (1) when it is provided with English Water closet Rs. 650 to Rs. 975; (2) when it is provided with Indian Water closet Rs. 630 to Rs. 945.

Abstract Of Quantities For A Flush Out Latrine: Plate 33.

Quantity.	Description of work.
288 c.ft.	... Earthwork, excavation.
141 c.ft.	... Concrete, broken stone in surkhi mortar.
376 c.ft.	... Brickwork in surkhi mortar.
4 c.ft.	... Archwork.
1 c.ft.	... Cutstone lintels.
740 sq. ft.	... Plastering with cement, ½" thick.
3·47 c.ft.	... Teakwood wrought and put up.
61 sq. ft.	... Roofing with plain Mangalore tiles including teak reepers.
11 r. ft.	... Zinc sheet gutter.
No. 3	... Wrought iron gutter holders.
No. 3	... Teakwood bracket stands for syphon flushing tank including fixing.
No. 3	... Indian closet basins including fixing, etc., complete.
No. 3	... Syphon flushing tanks with flushing pipe, chain including fixing complete.
No. 4	... 4" stoneware ½ bends.
No. 11	... 4" stoneware pipes.
No. 3	... 4" „ slant branches.
No. 3	... 4" „ right angle branches.
No. 3	... 4" „ 1/8 bends.
No. 1	... 4" „ silt trap.
Sum	... Laying and jointing stoneware pipes and specials.
No. 3	... Foot rests including fixing.
No. 1	... Cast iron cover over silt trap including fixing.
No. 1	... Cast iron light cover with frame, clear opening 24" × 24", including fixing.
No. 3	... Teakwood self-closing doors including frames, spring hinges, etc., complete.
No. 1	... 4" ventilating shaft, 20' out of ground, with cast iron ground base welded tube including clamps, fixing, etc.
Sum	... Wrought iron galvanized iron service pipe including stopcocks, fitting, laying and fixing, etc., complete.
116 sq. ft.	... Painting, 2 coats with Imperial zinc white.
No. 3	... Masonry sinks at seats.
	Sundries ...
	Total Rs....

Colonel Smyth's Indian Commode: Plate 34.

In the above plate is illustrated the type design No. 154 issued with proceedings of the Madras Sanitary Board, No. 269-S., dated 24-3-1914. The specification report which accompanied this design was as follows: The design, plate 34, prepared after the model of Colonel Smyth's Indian Commode can be adopted in all hospital and dispensary latrines. It can be used also for collecting samples of urine for purposes of analysis. It is obtainable from the English warehouse, Mount Road, Madras, at a cost of Rs. 8.

Urinals: Plates 35 And 36.

In the above plates is illustrated the type design No. 107 issued with proceedings of the Madras Sanitary Board, No. 125-S., dated 22-6-1910. The specification report which accompanied this design was as follows: The type design plan shows two urinals side by side, the floor level of both being 4'-3½" above ground level. The object of having the floor level

of the urinals above ground is to ensure that the bucket receptacle will be above ground level so that in the event of spilling taking place it will be easy to thoroughly cleanse the ground around the urinal and by the addition of a little fresh sand or gravel render the surroundings as clean as when the urinal was first erected. In the cesspool style of urinals it is found that the cesspool being below ground level becomes extremely objectionable and that it is next to impossible to remedy this nuisance. It has therefore been proposed to have the floor of the urinal above ground level so as to get over the necessity for a cesspool pit. 2. The following is a specification of the urinal: The urinal to be in two compartments each measuring 7′-5½″ × 6′ with walls of corrugated iron 6′ high and no roof allowing the floor to be open to the sun and air. The walls to be supported by L uprights let into the concrete floor and L horizontals. The floor of the urinal to be 4′-3½″ above ground level and to be carried on 2 concrete arches as shown in plan and to be reached by steps. The depth of the foundations should be increased in loose soil. In a place where brickwork or random rubble is cheaper than concrete, the whole of the foundations may be built of either of them. The superstructure may also be built of brickwork or coursed rubble, if found cheaper than concrete. The floor to be laid with Cuddapah slabs 1½″ thick and the centre of floor of each compartment to have a urinal pan built of white glazed tiles with a border of white glazed bricks. The top row of bricks to project 4 inches above floor level and to be used as a foot rest. The white glazed tiles to be laid with a slope as shown in the plan towards a vertical 1½ inch galvanized pipe 2′ long discharging into a bucket 15″ high and 12″ diameter resting on the ground. 3. A screen wall to be placed 2′ from front of urinal as shown in plan to screen bucket from observation. 4. The top of foot rests to be 4 inches above floor level and the bottom of corrugated iron to be ½ inch only above floor to prevent observation from outside but allow of escape of rain and flush water. 5. The estimated cost of the two urinals will vary from Rs. 270 to Rs. 405 according to locality.

Abstract Of Quantities For A Urinal: Plates 35 And 36.

Quantity.	Description of work.
161 c. ft. ...	Earthwork, excavation.
463 „ ...	Concrete, in surkhi mortar.
66 „ ...	Brickwork in mortar.
471 sq. ft. ...	Plastering with surkhi mortar, ½″ thick.
136 „ ...	Flooring with 1½″ Cuddapah slabs and pointing with cement.
333 sq. ft. ...	Corrugated iron sheet walling including angle iron supports and fixing.
36 l. ft. ...	White glazed bricks, 4½″ thick and fixing in cement.
4 sq. ft. ...	Flooring with white glazed tiles on cement, ½″ thick.
2 No. ...	1½″ galvanized wrought iron pipes, 2′ long including fixing.
2 „ ...	Galvanized iron buckets, 15″ high and 12″ diameter.
666 sq. ft. ...	Painting, two coats with chocolate colour.
	Special charges for planking the concrete above ground level and centering.
	Contingencies.
	Total Rs. ...

Temporary Latrines.

It is advisable that at all famine camps and fairs and festivals, there should be recognized places for defecation, provided with water for ablution, and that means should be employed to ensure that such sites be uniformly used. For such temporary congregations of men, permanent latrines are out of the question. Moreover it is no easy task to get sufficient number of scavengers for emergencies like this; hence latrines of a temporary character and such as would ensure the disposal of fæcal matter without handling must be employed. This can be provided for by the use of the trench system. One incorrect principle in making these trench latrines must be provided against. There is a tendency to make them deep and wide in the belief that labour and expense would be saved thereby. Thus it is not uncommon to see trenches made 3 feet wide and 3 feet deep. Such trenches can only be employed by persons squatting at the edge and it has frequently occurred that the earth has given way or that the persons have over-balanced themselves with serious consequences. But safety and convenience are not the only reasons why these huge excavations should be avoided. It has already been stated that nitrification proceeds actually only within the first 12 inches of soil and that indeed the most active change occurs within the first 6″ from the surface; consequently it is well where the final burial of the fæcal matter is contemplated to use at no time a depth exceeding 12″. As regards breadth, trenches should not be broader than 9″, this being the usual size from heel to heel of an Indian. Squatting: With this limited breadth, instead of the person using the trench sitting at the side, the position assumed should be that of squatting direct across the shallow trench; the result is that both fæces and urine are received into the trench and consequently, the surroundings are kept dry; whereas in the case of the old form, the approach or the pathway became unusable on account of soakage

from urine and washings from ablution. The trenches should be in lengths not exceeding 20 feet. Each length should be screened in with bamboo or other tatties fixed to casuarina or jungle posts placed at suitable intervals. The posts should be tarred, at any rate the portion planted in the ground should be tarred. The tatties should be fixed 6" off the ground. After defecation the persons concerned or the attendant should cover the mass with dry earth from the excavation. As soon as the trenches are filled, the bamboo tatty sides can be shifted to other positions as required. Where tatties are available and there is not sufficient land for the burial of night soil, the mixed earth and night soil should be removed daily and thus the trench can be used as long as desirable.

BUILDINGS: MAIN DETAILS OF CONSTRUCTION OF SLAUGHTER HOUSES AS GAINED FROM A STUDY OF PLANS.

Classification And Materials.

I cannot do better than quote here the following extract from Mr. Jones' Manual: "Slaughter-houses are arranged according to the class of animals to be slaughtered therein and, in India, are denominated bullock, sheep or pig slaughter-houses. The religious prejudices of the Hindus require that bullocks, sheep and pigs should be slaughtered apart from one another. The requirements of a slaughter-house may be briefly enumerated as follow: (1) The slaughter-house should be so enclosed as to permit ingress and egress being easily controlled by the superintendent in charge. (2) The slaughtering space should be roofed in. (3) The slaughtering sheds should be well ventilated. (4) Cisterns should be provided to hold a sufficient supply of water. (5) The floor of the slaughter-house should be arranged so as to enable it to be easily flushed from the cisterns. (6) Drains should be provided for carrying away the liquid filth from the slaughter-house. (7) Cesspools should be provided outside the slaughter-house into which the drains can discharge. (8) The flooring should be of hard and impervious material. (9) The lining of the walls should be of a hard and non-absorbent material. (10) Cooling and hanging rooms and lairs for animals are desirable. The size of a slaughter-house naturally depends upon the number of animals to be killed. Statistics as to the number killed annually are available in most Municipalities. No definite rule can be laid down, as in some parts of the country more beef and less mutton is eaten in certain towns than in others. In Madras city the annual consumption is about one bullock per 45 persons and one sheep per person. The size requisite for a sheep slaughter-house would be determined thus: Taking the population of a town to be 15,000, we have 15,000 sheep to be slaughtered in a year, or 43 sheep on an average daily. A period of from three to four hours is the usual duration of slaughtering. Taking the minimum period of three hours, 14 sheep would require to be slaughtered per hour. To slaughter one sheep and skin it, requires about 20 minutes, so that three sheep will be killed per hour and therefore floor space for $\frac{14}{3}$ or, for five sheep, will be required. Let this be increased by 50 per cent. to allow for fairs and festivals, or, say, a floor space for 8 sheep is required. The floor space required for one sheep is about 60 square feet which is $8' \times 7\frac{1}{2}'$. Masonry: The foundation and superstructure of slaughter-houses may be in either stone or brick; the slaughter-house should be built in chunam, but where economy is the object, portions of the structure may be built in clay except the following, *i.e.*, water cistern, cesspool, drains and pillars which should, as a rule, be constructed in chunam. Plastering: The whole of the interior walls and pillars of the building should be plastered with Portland cement mortar not less than half an inch thick in the proportion of 3 of sand or 2 of sand to 1 of cement. Over this there must be a rendering of neat cement. The outside of the building, if of brickwork, should also be plastered with cement, but, if of stone, pointing with cement will suffice. Flooring: It is an essential requisite of a slaughter-house that the floor should be evenly paved. Notwithstanding that there is some inconvenience to the butchers by reason of a certain slipperiness with a smooth floor, this, when weighed against the quick removal of blood, garbage, &c., cannot be considered a grievance. It is not advisable that the floors of a slaughter-house should slope towards the drains; in the first place the slope would cause the floor to be more slippery than if level; in the second place the cleansing probably would not be so effectually done; on the slope it could be sluiced with water, on the level, manual labour will be required and if squeegees, such as are used for railway station paved platforms, are employed, the cleansing can be very effectual. The floor may be formed of: (1) Flags. (2) Granite stones, dressed fairly smooth. (3) Well-burnt brick on edge in cement or hydraulic mortar plastered over with cement. (4) Concrete in cement or hydraulic mortar plastered over with cement. When flags are used the edges should be squared so that they may be laid with close joints. The flags should be laid over a layer of concrete not less than 4 inches thick, as a firm foundation is necessary. The flags shall be jointed with Portland cement. The flags should be such that their individual area does not exceed one square foot for each half an inch of thickness. A slaughter-house should not be paved with square granite stones unless their surfaces are finely chisel-dressed. The

cost of doing so will be prohibitive in most places. When bricks on edge are used, they should be laid in cement or hydraulic mortar on a foundation of not less than 4 inches of concrete. The floor must then be plastered with Portland cement mortar not less than half an inch thick consisting of 2 or 3 of sand to 1 of cement, laid in one coat with a rendering of neat cement. When concrete in cement or hydraulic lime is used, the concrete should be not less than 9 inches thick and be plastered over with cement as above described. Drainage: The drains should have a fall of not less than 1 in 100, but greater than this if it can be arranged. The drains should be 6 inches in width. The bottom should have either a semi-circular or oval shape, preferably the latter. The drains should be formed of concrete in cement or hydraulic mortar, and coped stone with brick on edge in cement and plastered with cement, or to be made of some equally non-absorptive material and of a design such as will not allow of any leakage. Cesspools: The cesspools ought to be outside the slaughter-house. They should be of ample capacity to receive all the solid matter from the slaughter-house and also a portion of the water used for cleansing. If an overflow is provided from the cesspools and no sewers exist, the water overflowing should be used to irrigate some small area of land. The cesspools should be built in chunam mortar and plastered with cement in the proportions already stated. Water-supply: The cistern should be so arranged that it can be filled from the outside. The bottom of the cistern should be at a sufficient height to enable every portion of the floor of the slaughter-house being flushed. The cistern should be built in chunam and plastered with cement. Design: The roof may be a tiled one on wooden rafters or covered with corrugated iron sheets if considered desirable on the grounds of economy and facility of erection. Slaughter-houses ought, if possible, to consist of open sheds, all surrounded by a brick wall or other closed fence. This plan admits of thorough circulation of air."

Proposals For Slaughter Houses.

All proposals for slaughter houses should be accompanied by the following plans, estimates and report: "1. Site-plan, scale 330 feet=1 inch (village map or town survey) showing (i) position of work and surroundings for a distance of 1,000 feet from the site; (ii) all water sources and the use to which they are put; (iii) the trend of the surface by means of arrows. 2. Detailed estimates and specifications of the proposed work. 3. Describe the nature of the soil and subsoil of the site, and give a section of a trial-pit. 4. Plan and section of slaughter-house proposed, if not on type-design, to a scale of 6 feet=1 inch. The section should show clearly the levels of the various portions of the slaughter-house proposed, the levels of all platforms, drains, etc., the levels of adjoining streets and drains; the plans must include the various streets around the slaughter house and show the line of any street drains into which the discharge from the slaughter-house will enter. 5. A statement of the number and description of animals to be killed on an average daily, and the number of hours within which slaughtering and following operations usually take place. 6. Describe carefully the nature of the water-supply source intended for use in the slaughter-house. If the supply has not been approved by the Sanitary Commissioner or his Deputy, forward a letter from the District Medical and Sanitary Officer showing that he approves of the source of water-supply. 7. Indicate the means taken to protect the water-supply source from pollution by ingress of surface drainage, subsoil soakage or direct pollution. 8. State what measures are contemplated for the disposal of the floor washings, the blood, offal and gut contents, respectively. 9. State what plant, and of what capacity, is available for collecting any, or all of these. 10. Is there any land within a reasonable distance on which the sewage and gut contents can be placed with the object of utilising them for garden or agricultural purposes?"

A Slaughter House Intended For Bullock Or Sheep: Plates 37 And 38.

In the above plates is illustrated the type design No. 155 issued with proceedings of the Madras Sanitary Board, No. 373-S., dated 22-4-1914. The specification report which accompanied this design was as follows: General: The arrangement consists of an open yard surrounded on all sides by high walls, a cooling room, lair for cattle, and the necessary water-supply and drainage arrangements, the whole of the buildings being in a compound sufficiently large to permit of an open space at least 20 feet wide around the buildings. A suitable compound wall is also provided. Lair: This consists of an open space or yard 18 feet square provided with an enclosure wall and a ramp for entrance. The floor of the enclosure is laid with sand and a water trough with overflow arrangement for disposal of spill water is provided. Cattle or sheep will be led from the lair through the two doorways, the first doorway being provided with a plank door and the second being an arched opening. Slaughtering place: The slaughtering place will measure 20′×14′ and will be floored with asphalt over concrete. The floor will slope towards the cooling room (2″ in 14′) and a 6-inch drain will be provided to carry away the washings. A hydrant for sluicing purposes will be provided on the high side. As shown in the plan

there will be two ring bolts in the floor to enable cattle to be drawn up into position. The slaughtering place will be surrounded by walls 12 feet high and will be open to the sky but protected by expanded metal covering so as to keep out crows. The two rolled steel beams which support the expanded metal frame will be utilised in addition to suspend the pulley and chain arrangement shown in the plan which arrangement is intended to be used for suspending carcasses of cattle for skinning and dressing purposes. Cooling room: Adjoining the slaughtering place there will be a cooling room 20′ × 9′ provided with three large windows for ventilation and with one open gable and filled in with expanded metal and fly-proof gauze. Supported from two teak cross beams (4″× 6″ each) there will be two longitudinal teak beams (4″ × 4″ each) along each side of the room to which hooks as shown in the plan will be placed. The floor will be of asphalt and there will be a hydrant so that the floor can be sluiced out, a suitable drain being provided in the centre of the floor. Water-supply and drainage arrangements: In towns possessing piped water-supplies the water-supply required by the slaughter-house will be obtained by a 2-inch connection. In those towns which have not the advantage of such piped supplies, or, where the site of the slaughter-house is distant from the town, a suitable well, close to the slaughter house, (type-design No. 144/1913 shown in plate 156) should be provided and fitted with a suitable pump or pumps. From this well the water should be pumped daily to an iron tank on the roof of entrance to the slaughter-house and from the tank there should be three connections, one to the hydrant in the slaughtering place, one to the hydrant in the cooling room and a ¾ inch connection with tap to the water trough in the lair for cattle. The drainage arrangements of the slaughter-house will consist of open drains, one in the slaughtering place and one in the cooling room. These drains will join as shown on the plan and will discharge into the cesspool outside the slaughter-house. This cesspool which is of ample dimensions and which should be made with a rounded bottom to facilitate emptying by buckets, should be emptied daily into conservancy carts and the contents removed to the trenching ground and immediately covered with dry earth. The spill water from the overflow of the trough in the cattle lair should be disposed of in the filter well as shown in the plan. Cattle and sheep slaughter-house: The design shown in the plan represents the slaughter-house as arranged for cattle. When a sheep slaughter-house is required, then, the hoisting arrangements in the slaughtering places and the ring bolts in the floor may be omitted in construction. Cost: At Madras rates the cost will be Rs. 5,500.

Abstract Of Quantities For A Slaughter House Intended For Bullock Or Sheep: Plates 37 And 38.

Quantity.	Description of work.
1,718 c. ft.	... Earthwork, excavation.
1,570 „	... Earth-filling in basement.
145 „	... Sand-filling.
302 „	... Gravelling for ramp.
1,257 „	.. Concrete, broken brick in chunam.
751 „	... Country brick, third sort in chunam for foundation.
999 „	... Country brick, third sort in chunam for basement.
2,168 „	... Country brick, first and second sort in chunam for superstructure.
72 „	... Country brick, first and second sort for archwork.
5,023 sq. ft.	... Plastering with cement 1 : 2.
68 „	... Cuddapah paving slabs.
2 c. ft.	... Cutstone.
600 sq. ft.	... Flooring with asphalt, ½″.
4·57 cwts.	... Girder, 4″×7″×16 lbs.
Lump sum	... Iron grating.
No. 2	... Iron buckets.
514 sq. ft.	... Roofing with Mangalore tiles with ceiling tiles including reepers.
417 „	... Expanded metal with wooden frame.
52·60 c. ft.	... Teakwood, wrought and put up.
48 sq. ft.	... Teakwood gate.
124 „	... Teakwood doors, batten with hinges, etc., complete.
84 „	... Teak windows with expanded metal screen and fly-proof gauze.
77 „	... Terracing, 9″ thick.
49 r. ft.	... Cornice work.
No. 4	... Pulleys.
14 sq. ft.	... Expanded metal screens with fly-proof gauze including frames, etc.
No. 1	... Water tank, 4′ × 4′ × 4′ to hold 400 gallons of water, piping 200 feet, two hydrants and taps including fixing, etc.
88 r. ft.	... Iron chains including hooks, etc.
No. 6	... Ring bolt hooks.
No. 5	... Finials.
166 lbs.	.. Ironwork.
1,539 sq. ft.	... Painting doors and windows.
616 „	... Woodoiling.
	Contingencies, tools and plant and petty supervision, 12½ per cent.
	Compound wall for 382 feet with iron gate as per estimate below.
	6 feet diameter of well as per type design No. 144 shewn in plate 156, with semi-rotary pump. Total Rs. ...
	Compound wall.
40 c. ft.	... Earthwork.
3 „	... Filling.
30 „	... Concrete in chunam.
87 „	... Brick in chunam.
154 sq. ft.	... Plastering in chunam.
	Contingencies, 5 per cent.
	Tools and plant, 5 per cent.
	Petty supervision, 2½ per cent.
	For a bay of 10 feet, Total.
	For 370 feet of 37 bays.
	Gate, 10 feet wide, 6′ high, and side pillars. Total Rs. ...

BUILDINGS: MAIN DETAILS OF CONSTRUCTION OF HOSPITALS AS GAINED FROM A STUDY OF PLANS.

Instructions For Guidance In Designing Hospitals.

The following instructions in regard to the designing of hospitals have been issued by the Madras Sanitary Board with their Proceedings No. 838-S., dated 28th November 1913. 1. Under rule 10 of the rules regulating the constitution and functions of the Sanitary Board published in G.O. No. 1081 L., dated 2nd September 1903, and the modifications sanctioned in G.O. No. 1000 L., dated 14th June 1913, every estimate exceeding Rs. 10,000 (exclusive of the cost of site) for works connected with hospitals, which is proposed to be undertaken by any Local Board or Municipal Council, must be submitted for the approval of the Sanitary Board. 2. (*a*) In all cases in which it has been decided that the buildings shall be executed by the Public Works Department, the same procedure shall be adopted as is laid down in G.O. No. 981 W., dated 15th September 1910, *i.e.*, the Chairman of the local body concerned will obtain from the Executive Engineer of the division, a rough estimate of the cost of the buildings proposed which he will submit to the Secretary, Local and Municipal Department, through the Sanitary Board for obtaining administrative sanction of Government. These cases need not be sent through the Sanitary Engineer and the Sanitary Commissioner. As such administrative sanction necessitates an examination of the arrangements for financing the scheme, the Chairman should submit definite proposals for this. (*b*) All other cases will be forwarded through the Sanitary Commissioner to the Sanitary Engineer who will accord technical sanction if the estimate does not exceed Rs. 10,000 and forward estimates for more than this amount to the Sanitary Board. (*c*) When a local body proposes to build a hospital containing above 50 beds, the rough estimate should be accompanied by a report containing full information on the following points: (1) a history of the proposal and the reasons which have led to it; (2) if a hospital or dispensary has previously existed, information as to the attendance of patients at it during each of the last five years under the following headings: (*a*) years, (*b*) total number treated, in-patients, (*c*) total number treated, out-patients, (*d*) average sick daily, in-patients, (*e*) average sick daily, out-patients, (*f*) maximum number of in-patients treated on any one day and (*g*) remarks; (3) an estimate of the population from which the patients to be now provided for will be drawn; (4) the approximate area which this population inhabits; (5) a list of the buildings proposed to be provided in the hospital and in respect of accommodation for in-patients the number of beds for Europeans or Eurasians and Indians, males and females, separately under each of the following classes: (*a*) general diseases and surgical cases, (*b*) isolation wards for special cases, cholera, small-pox, venereal (females), septic cases, and dirty cases, (*c*) lying-in and delivery cases, (*d*) caste patients, with an administrative block, operating room and subsidiary buildings; (6) information, (where additions are proposed, to an existing institution, information on this clause is not required) as to the site under the following heads: (*a*) the aspect and conformation of the ground with special reference to its elevation, free access to sunlight and exposure to prevailing winds, with all available information as to health conditions; (*b*) the nature of soil with reference to its power of retaining heat and moisture, the level of sub-soil water and necessity for and possibility of drainage; (*c*) the total area available and how much of that area will be required for buildings, gardens, roads and paths; (*d*) the accessibility of the site both to patients and medical staff; (7) the system proposed for water-supply; (8) the system proposed for the collection and ultimate disposal of sullage water, night-soil and rubbish. The above report should be accompanied by a site-plan showing the immediate surroundings of the proposed hospital and the proposed arrangement of the buildings. Even if it is intended, owing to want of funds, not to erect all the buildings at once, their site should be determined and marked on the plan. 3. Site: (1) The site should be selected by the Revenue and Local or Municipal authorities in consultation with the District Medical Officer and the Public Works Officer concerned. (2) The procedure laid down in G.O. No. 1319 W., dated 13th November 1909, should be followed in all cases in which it is proposed that the buildings should be constructed by the Public Works Department. When the site has been chosen by the Local Committee, a copy of the site-plan shall be sent to the Chairman of the local body concerned. Should the Sanitary Commissioner or Sanitary Engineer visit the place on tour, the Chairman will show them the site and will report direct to the

Board any criticisms which either of those officers may have to make; and will send at the same time a copy of the report to the Sanitary Commissioner or the Sanitary Engineer, as the case may be, for perusal. (3) The site for a general hospital should be so chosen as to be easily accessible to the population for whose use it is intended, and should, therefore, be on or near a main road. In all instances, as large an area as possible should be obtained, so as to provide for future extensions as well as for present requirements. Ordinarily one acre of site should be allowed for every twenty beds, and in no case should less than one acre for forty beds be provided. (4) An isolation hospital should also be provided with as large an area as possible, and in no case should less than one acre for every twenty beds be allowed. No ward for the treatment of patients in any such hospital should be less than forty feet from the boundary of the hospital area. If the hospital is intended for cholera, it should stand on an open site, usually not farther from the thickly inhabited part of the town to be served than 400 yards. In choosing a site for a small-pox hospital the following requirements should, as far as feasible, be observed: (*a*) the site must not have within a quarter of a mile of it either a hospital, whether for infectious diseases or not, or any similar establishment, or a population of as many as 200 persons; (*b*) the site must not have within half a mile of it a population of as many as 600 persons, whether in one or more institutions, or in dwelling-houses; (*c*) even where the above conditions are fulfilled, a hospital must not be used at one and the same time for the reception of cases of small-pox and of any other class of disease. 4. As regards the general arrangement of the various buildings of a mufassal hospital on a site, and detailed designs for the individual buildings, Government approved and issued with G.O. No. 1466 L., dated 11th October 1912, certain type-designs for adoption. As pointed out in this order, the type-designs have intentionally been drawn up on elastic line and it is not necessary rigidly to follow them in all cases. Deviations will be permitted when warranted by considerations of economy and local conditions. The following general principles should be observed: (1) there should be free circulation of air around and between each ward-pavilion; (2) the space between each ward-pavilion should be well exposed to sunshine; (3) the distance between two adjoining buildings in any direction should ordinarily not be less than the height from ground-level to the top of the roof of the higher of the two buildings, and in no case should be less than the height from ground-level to the eaves of the higher building; (4) the hospital enclosure should be large and surrounded by a dwarf pierced wall or by railings, and should have only three gates, *viz.*, the main entrance, the entrance to the out-patient department, and an exit near the mortuary. Inside the compound should be a garden with seats under trees or sheds for the use of convalescents. 5. Baths: For convalescents there should be two general bath-rooms one for each sex. For patients unable to leave the wards, a covered bath on rubber-tyred wheels should be supplied, one for every 32 beds. 6. Special wards: Every general hospital should be provided with at least two isolating wards, one for each sex, to which suspicious cases can be removed pending diagnosis. A separate female venereal ward and a lying-in and delivery ward are required unless special hospitals for the purposes indicated have already been provided. 7. Isolation hospitals: The site should be sufficiently commodious to admit of the erection of wards or huts for different infectious diseases at least 40 or 50 feet apart and these wards and huts as well as all subsidiary buildings should be at an equal distance from the boundary wall. There should only be sufficient beds for cholera cases to deal with the class of patients who have no habitation of their own or where the private accommodation is inadequate. As a rule, cholera cases among the general population will require to be treated in their own houses, but separate arrangements should be made for housing the unaffected inhabitants of infected houses. In isolation hospitals, there must be a separate subordinate medical staff and establishment for the care of the patients. 8. Lying-in hospital: It is desirable to have this quite separate from the ordinary hospital and with a separate establishment. It must be located near the centre of the population for whose use it is intended. There should never be more than four beds in a ward which means eight patients including infants; the floor and air space should be calculated as for an isolation hospital. There should not be more than eight beds in one unit consisting of not more than two wards. The principles of construction should be the same as those detailed above. There should be two separate delivery wards for each unit, one to be under cleaning whilst the other is in use: there should be a bath-room or scullery to each with plenty of water, and means for disinfecting soiled clothing. The floor space in these delivery wards should not be less than 150 square feet and the floors should be on the same level as those of the wards; they should be joined to the lying-in wards by a covered passage open to the sides. It is a good plan to have a by-ward in connection with the delivery ward for the temporary care of specially exhausted cases. The scullery and latrine for the use of patients in the lying-in wards should be under a separate roof and joined by a covered passage open at the sides; the attendant's room and the store-room may be in the verandah

corners. No regular dispensing room is necessary if the maternity hospital is near the main or municipal hospital; if not, a small one is required. When it is situated far from the hospital, a separate room for the office of the Medical Officer is required; in such an institution, there should also be a waiting room for patients and a well lit examination room. Isolation huts for septic disease are very necessary. If possible, one unit should always be kept empty in order that all may be periodically aired. There should be a low truck on wheels with India rubber tyres for the removal of patients from the delivery ward. 9. Ward furniture should be simple and strong, of iron, where possible; it should be easily cleaned and so constructed as not to harbour vermin. There should be as little furniture as is compatible with the comfort of the patients and attendants. 10. In addition to the more important buildings the subsidiary buildings should consist of (*a*) General store building. (*b*) Kitchen. (*c*) Laundry. (*d*) Quarters for medical subordinates. (*e*) Firewood and straw store-room. (*f*) General latrines. (*g*) Mortuary and post-mortem room. (*h*) Out-patient department. 11. Laundry: This should be adapted to native methods of washing and as open as possible, with tanks for soaking soiled clothes in and sloping slabs or stones for washing them on. The boilers and fire places should be of the same materials and pattern as the dhobies of the place use. There should be an open corrugated iron or other shed for drying in during rain and where ironing may be carried on. There should be two small rooms with doors, one for temporarily storing soiled clothes, the other for clean clothes; these rooms may be of corrugated iron. In connection with this laundry there should be another room for disinfecting clothing and a separate tank for soaking and washing it in. 12. Quarters: Quarters for medical subordinates, nurses, hospital attendants and all menials should be provided on or near the premises. 13. Store-room for firewood and straw: There should be two small corrugated iron rooms under the same roof—one for firewood and the other for straw—for which no type-plans are needed. 14. General latrines: A general latrine constructed on one of the Sanitary Board's type-plans should be provided for males and another for females allowing one seat or perch to ten persons living in the hospital compound including patients and attendants. In locating these latrines, attention should be paid to the prevailing winds; they should stand well to the leeward of the wards and not nearer than forty yards. Adjoining the latrine, accommodation should be provided for a disinfecting tub as well as a receptacle with racks on which bed-pans may be retained for inspection. 15. Disposal of filth and refuse: The disposal of sewage and sullage water must vary with the means at command. If the town possesses a pipe sewerage system, the plans for connection with this should be specially approved by the Sanitary Board. If not, one of the various methods suitable for single establishments should be employed. If the expense of conveying by pipes combined night-soil and sullage water to suitable land for disposal by irrigation be prohibitive, urine and latrine washings should be received and fœcal matter be collected in the latrines separately, the former in trapped and ventilated cesspools and the latter in well-tarred iron receptacles. The sullage water should be removed from the premises in cylindrical iron tank carts, and the nightsoil in suitable covered iron conservancy carts. The sullage water and the nightsoil thus collected should be disposed of in accordance with the system in vogue in the town; but where possible in the case of large hospitals, a septic tank should be provided, to be followed by treatment on land, preferably under-drained, or by any artificial application of biological methods for sewage purification. 16. Water supply should be ample in quantity and as pure as possible. If from a well, the ground in the vicinity should be kept clean and free from rubbish and a masonry platform, parapet and lining should be provided so as to prevent the return of spilt water or the entry of other impurities. The mouth of the well should be covered and a pump should be employed for drawing water. When there is no public water-supply the addition of a tower to the administrative block served by a force pump would facilitate the distribution of water under pressure which should certainly be arranged for at the kitchen, latrines, operating-room, bath rooms, dispensing room, post-mortem room, laundry, out-patients department, etc. In general hospitals, arrangements should be made for fire engine and fire-hoses. Fire buckets should be hung up in each building and kept full of water. In temporary and semi-permanent buildings, special precautions against fire are particularly necessary.

Present Type Designs.

In plates 39 to 94 are shown the type designs for hospital buildings which were in force on the 1st of April 1916. Site plan, type design No. 133 issued with proceedings of the Madras Sanitary Board, No. 686 S., dated 10-12-12 is shown in plate 62. I have given the specification reports and the abstracts of quantities for each type design separately. The Medical and the Surgical Ward Units as adopted in the Presidency of Madras are shown in plates 43 and 45. The Medical Ward Unit as shown in plate 43 consists of 20 beds for males and 20 beds for females. The male and the female wards are separated by the Administrative

·Block containing a Nurse's Room, a Ward Kitchen, a Linen Room and a Surgeon's Room. Separate Bath Rooms and Latrines are provided for males and females, connected to the main ward by covered passages, 10 feet in length. The Medical Ward Unit as adopted in England is shown in plate 41. On a perusal of this plate it will be observed that the ward for males consists of 22 beds and the ward for females of 16 beds. In this case also the wards are separated by the block of Administrative Buildings. The different rooms comprising the Administrative Block of the Medical Ward Unit as adopted in England are shown in plate 41. In plate 44 is shown the block of the Administrative Buildings attached to the main wardshown in plate 43 as finally approved by Government. In plate 45 is shown the Surgical Main Ward of 40 beds as per type design of the Madras Sanitary Board. In this case also the centre Administrative Block should be as shown in plate 44. The Surgical Ward Unit as adopted in England with the different rooms comprising the Administrative Block is shown in plate 42. The general specification report as issued by the Madras Sanitary Board for the type designs shown in plates 39 to 94 was as follows: Floors: Floors should wherever possible be laid with a slight slope in one direction towards channels along one wall of the rooms, or in the case of verandahs towards the outside of the verandah to facilitate flushing with water and disinfectants. The surface of all floors must be continuous and not interrupted by projecting door sills or thresholds. For flooring surfaces in wards, operation rooms and mortuaries where an impervious unjointed floor surface is desirable, Bird's Indian Patent stone, or Bombay Co.'s Truscon floor enamel over ½" Portland cement are recommended. These materials readily lend themselves to the formation of channels along walls. Walls: Internal walls in wards, operation rooms, dispensaries and mortuaries should be rendered with Portland cement from floor to ceiling and painted with paripan "glossy" or other "glossy" white washable paint. All internal corners should be rounded in wards, operation rooms, mortuaries and dispensaries. External wall surfaces, if built of stone should preferably be pointed with cement when good building-stone is available and if of brick should be plastered and whitewashed. Iron work: Iron work in rolled steel joists, tie bars, etc., should be arranged so as to afford as few ledges or surfaces upon which dust can collect as is possible. Where jack arches are used, the tie bars should be embedded in the masonry of the arches. Windows: When within reach all windows should be pivoted at top and bottom. Doors: There must be no door sills projecting above floor level. Wooden door sills should be avoided where possible. Raised panel doors catch dust. Flat panels should be used. Doors in wards, operation rooms, dispensaries, mortuaries and wherever stretchers may have to pass, should be not less than 4′ 6″ between masonry jambs. In plate 95 are shown the detailed drawings of Jack-Arched and Mangalore Tiled-Roofs. The Chief Engineer, P.W.D., has issued a Circular regarding the roofing of Hospital Buildings and his orders on this question were as follow: 1. In the type-designs for hospital buildings provision is made for fibro-cement slates or poilite for the roof covering of verandahs. 2. The Chief Engineer has since had under consideration the advisability of continuing the use of poilite or fibro-cement slates in place of Mangalore tiles and has come to the conclusion that there is no advantage in poilite or fibro-cement slates over Mangalore tiles for verandahs of hospitals except in districts where Mangalore tiles are difficult to obtain. One advantage claimed for poilite or fibro-cement slates was that a roof covered with these materials could be laid at a lower slope than that of Mangalore tiles. Type-designs for hospital buildings were therefore issued showing the verandah roofs of a slope of 1 in 5, but it has since been proved that a roof covered with poilite or fibro-cement slates requires the same slope as that usually provided for Mangalore tiles. 3. Superintending Engineers are requested to provide in their estimates for verandah roofs with a pitch of 30° and to increase the height of main walls of wards, etc., as shown in plate 93. 4. The Chief Engineer is of opinion that the only cases in which poilite or fibro-cement slates could be used with advantage would be on large buildings of the workshop type which have a large expanse of plain roofing and where lightness of roof construction may be of the utmost importance. In such cases poilite or fibro-cement slates of Roman tile pattern would perhaps be more economical than Mangalore tiles, both in initial cost and upkeep. In plate 94 are given the details of the U. S. Sash Windows as adopted in the type designs of hospital buildings. In plate 65 is given the design for an Out-patient Dispensary, of a Hospital in India as issued by Major M. H. Thorneely, I.M.S., Civil Surgeon, Arrah, and his report accompanying this design was as follows: It is proposed to build a new hospital at Buxar, the head-quarters of the Buxar Sub-division of the Shahabad district and the scheme to be adopted for the out-patient department will be on the lines shown in the accompanying sketch plan which has been drawn by Messrs. Briggs Wolstenholme and Thorneely, F.R.I.B.A., Architects of Liverpool from a description of the requirements given. As requirements are similar in most head-quarters and sub-divisional hospitals in Bengal and as the only Type plan at present available does not satisfactorily meet those requirements the plan may be of help to

other Civil Surgeons who have similar projects under consideration. There are a few features which require alteration. Thus there is no need for the doors between the lobbies on each side of the Assistant Surgeon's Consulting room. A wall with an arch of 8 feet width and 10 feet or more high with a railing across will be substituted at Buxar in as much as it will allow the Assistant Surgeons to supervise to some extent what is going on in the compounding room. Verandahs on the north side instead of the lobbies shown are also being provided at Buxar.

Administrative Block: Plates 39 And 40.

In the above plates is illustrated the type design No. 115 issued with proceedings of the Madras Sanitary Board, No. 245-S., dated 19-3-1914. The specification report which accompanied this design was as follows: Foundations: A depth of 3 feet is provided, the lower 1′ 6″ will be concrete, broken brick in lime mortar and the upper 1′ 6″, brick in lime mortar. The depth and width of foundations will be settled locally according to the nature of the soil. Basement will be brick in lime mortar 1′ 6″, high. Pressure: The maximum pressure on the soil in foundations is 0·41 ton per square foot. Superstructure will be brick in lime mortar for walls and archwork. Cutstone corbels, base stones for posts and sill stones for doors are provided. Woodwork: One of the timbers mentioned in Circular No. 2040-C., dated 27th April 1909, as applicable to Table I in Circular No. 234-C., dated 9th January 1908, should be used. Doors, windows and ventilators will be of teak as detailed below:

A: Door, $\frac{1}{3}$ panelled and $\frac{2}{3}$ glazed...	4′-6″×8′-6″.
B: Door, panelled	4′-6″×8′-6″.
C: Door, $\frac{1}{3}$ panelled and $\frac{2}{3}$ glazed...	4′-0″×8′-0″.
D: Door, panelled	4′-0″×8′-0″.
E: Door, battened	3′-0″×6′-6″.
F: Door, battened	2′-6″×6′-6″.
G: Window, glazed	3′-6″×5′-0′.
H: Window, battened ...	3′-0″×4′-0″.
I: Window, glazed	3′-0″×4′-0″.
K: Ventilator, glazed	3′-0″ ×1′-9″.
L: Window, iron sash ...	6′-1$\frac{13}{16}$″×6′-3$\frac{1}{8}$″.

Roofing: Roof over main rooms and examination room will be of Mangalore tiles imbedded in mortar over flat tiles on teak reepers and over verandah and outbuilding, fibro-cement slates on teak reepers. Flooring: Will be paved with any patent stone over 4″ concrete and pointed with cement. Finishing: The interior of the main building and examination room will be plastered with cement, $\frac{1}{2}$″ thick and painted with paripan or other suitable white glossy washable paint. The interior of bath and staff latrine will be plastered with cement. The exterior of the whole will be plastered with two coats of lime mortar. Doors, windows and ventilators will be painted with three coats of approved colour and the roof timbers with two coats. Cost: The building shown upon the drawings is estimated to cost Rs. 7,700 to Rs. 11,500 according to locality.

Abstract Of Quantities For An Administrative Block: Plates 39 And 40.

Quantity.	Description of work.
5,030 c. ft ...	Excavation for foundations.
2,339 c. ft. ...	Filling in basement with earth.
2,548 „ ...	Concrete, broken brick in lime mortar.
2,473 „ ...	Brick in lime mortar (foundations and basement).
4,367 „ ...	Brick in lime mortar (superstructure).
185 „ ...	Do. (archwork).
42 „ ...	Cutstone work.
279·96 „ ...	Timber, wrought and put up.
63 sq. ft....	Barge board, $\frac{3}{4}$″ thick including painting complete.
141 „ ...	Doors, 1/3 panelled and 2/3 glazed with frames and fittings complete.
141 „ ...	Doors, panelled with frames and fittings complete.
111 „ ...	Doors, battened with frames and fittings complete.
252 „ ...	Windows, glazed with frames and fittings complete.
12 „ ...	Windows, battened with frames and fittings complete.
84 „ ...	Ventilators, fixed, glazed with frames and perforated zinc sheet betwen shutters.
39 „ ...	Iron sash window.
2,045 „ ...	Roofing with Mangalore tiles imbedded in mortar over flat tiles including teak reepers.
2,256 „ ...	Roofing with fibro-cement slates including teak reepers complete.
2,339 „ ...	Levelling course of concrete, 4″ thick.
2,629 „ ...	Paving with any patent stone, 2″ thick, and pointing with cement.
84 „ ...	Paving with Cuddapah slabs and pointing with cement.
5,482 „ ...	Plastering with cement, $\frac{1}{2}$″ thick and painting with paripan or other white glossy washable paint.
531 „ ...	Cement plastering, $\frac{1}{2}$″ thick.
3,251 „ ...	Plastering with lime mortar, two coats.
1,174 „ ...	Painting, three coats.
3,374 „ ...	Do., two coats.
62 „ ...	Brick-nogged partition.
Lump sum ...	Shelves in store room.
	Contingencies at 5 per cent.
	Petty supervision at $2\frac{1}{2}$ per cent.
	Total Rs.

A Main Ward Of 40 Beds (Medical): Plate 43.

In the above plate is illustrated the type design No. 116 issued with proceedings of the Madras Sanitary Board, No. 686-S., dated 10-12-1912. The specification report which accompanied this design was as follows: Foundations: A depth of 3 feet is

provided, the lower 1 foot 6 inches being concrete of broken brick in lime mortar and the upper 1 foot 6 inches, brick in lime mortar. The depth and width of foundations will be settled locally according to the nature of the soil. Basement: Brick in lime mortar, 2 feet high. Pressure: The maximum pressure on the soil as drawn is 0·68 ton per square foot. Walling: Walls, archwork and cornice will be built of brick in lime mortar. Internal corners should be rounded. The partition in the female ward will be brick in cement, 4½ inches thick, reinforced with two strips of hoop iron in every third course. Cutstone work: Templates under girders and trusses, verandah wall brackets, bases under verandah posts, lintels over ventilators and blocks for door frames. Woodwork: One of the timbers mentioned in Circular No. 2040-C of 27th April 1909 as applicable to Table I of Circular No. 234-C of 9th January 1908 should be used. Doors, Windows and Ventilators: Teak as per list given below:

A: Doors, ⅓ panelled & ⅔ glazed	...	4′-6″×8′-6″.
B: Doors, batten ...	...	2′-6″×6′-6″.
C: Windows, fully glazed	...	4′-0″×7′-0″.
D: Windows, fully glazed	...	3′-0″×4′-0″.
E: Ventilators, glazed with wire netting	...	4′-0″×2′-0″.

Roofing: The central block will be roofed with Madras terracing with a course of brick on edge, 3 inches concrete, 3 courses of flat tiles, top and bottom, lime plastered. The ward will be roofed with Mangalore tiles over ceiling tiles on teak reepers. Verandahs, bath rooms and latrines will be roofed with fibro-cement slates on teak reepers. Flooring: With the exception of bath rooms and latrines, the flooring will consist of any suitable class of patent stone over 4 inches concrete. Bird's Calcutta Indian patent stone, or Bombay Co.'s (Madras) Truscon flooring enamel laid over a coat of cement plaster, is recommended. The bath rooms and latrines should be floored with thin Cuddapah slabs pointed with cement, or ½ inch Portland cement laid over 4 inches concrete. Cup-boards: A cupboard lined with galvanised iron sheets riveted together at joints and painted with glossy white washable paint should be provided in the linen room. Finishing: The interior of wards and the surgeon's room and laboratory will be painted with paripan or other suitable washable paint over a coat of Portland cement plaster, ½ inch thick. The interior of bath and latrine will be rendered with ½ inch Portland cement plaster. The interior of all other rooms and passage will be plastered with two coats of lime mortar. The exterior throughout will be plastered two coats. Doors, windows and ventilators and ironwork will be painted three coats of white paint and the roof timbers, two coats of white paint. Cost: The building shown upon the drawing is estimated to cos from Rs. 23,050 to Rs. 34,600 according to locality

Abstract Of Quantities For A Main Ward Of 40 Beds (Medical): Plate 43.

Quantity.		Description of work.
12,616 c. ft.	...	Excavation for foundations.
12,870 "	...	Filling in basement with earth.
6,389 "	...	Concrete, broken brick in lime mortar.
7,666 "	...	Brick in lime mortar (foundation and basement).
10,149 "	...	Brick in lime mortar (superstrcuture).
539 "	...	Archwork, brick in lime mortar.
137 r. ft.	...	Plaster cornice work.
134 c. ft.	...	Cutstone work.
0·98 ton.	...	Rolled steel girders.
0·98 "	...	Hoisting and setting the girders.
692 lb.	...	Wrought iron work.
1,061·32 c. ft.	...	Teakwood, wrought and put up.
96 sq. ft.	...	Barge board, ¾″ thick, including three coats of painting.
383 "	...	Teak doors, ⅓ panelled and ⅔ glazed, with frames and fittings, complete.
130 "	...	Teak doors, battened, with frames and fittings, complete.
1,504 "	...	Teak windows, fully glazed with frames and fittings, complete.
384 "	...	Teak fixed glazed ventilators with perforated zinc sheet between them.
1,620 "	...	Terrace roofing with brick on edge, 3″ concrete, three courses of flat tiles, top and bottom plastered.
5,312 "	...	Roofing with Mangalore tiles over ceiling tiles with air spaces, complete.
6,280 "	...	Roofing with fibro-cement slates
8,579 "	...	Levelling course of concrete, 4″ thick.
9,281 "	...	Paving with patent stone.
518 "	...	Rendering with ½″ Portland cement.
8,869 "	...	Plastering with lime mortar, two coats (exterior).
5,495 "	...	Do. do. (interior).
5,986 "	...	Plastering with cement and painting with paripan.
1,019 "	...	Plastering with cement, ½″ thick.
12,187 "	...	Painting, two coats.
3,063 "	...	Painting, three coats.
225 "	...	Brick nogged partitions with frames, etc., complete.
355 "	...	Brick in cement partition, 4½″ thick, reinforced with two strips of hoop iron every third course.
32 "	...	Swing screen door with frames, etc., complete.
21 "	...	Cup-board lined with galvanized iron sheets including painting.
		Contingencies at 5 per cent.
		Petty supervision at 2½ per cent.
		Total Rs. ...

A Main Ward Of 40 Beds (Surgical): Plate 45.

In the above plate is illustrated the type design No. 117 issued with proceedings of the Madras Sanitary Board, No. 686-S., dated 10-12-1912. The

specification report which accompanied this design was as follows: Foundations: A depth of 3 feet is provided, the lower 1 foot 6 inches being concrete of broken brick in lime mortar and the upper 1 foot 6 inches, brick in lime mortar. The depth and width of foundations will be settled locally according to the nature of the soil. Basement: Brick in lime mortar, 2 feet high. Pressure: The maximum pressure on the soil as drawn is 0·68 ton per square foot. Walling: Walls, archwork and cornice will be built of brick in lime mortar. Internal corners should be rounded. The partitions in the main wards will be brick in cement 4½ inches thick reinforced with 2 strips of hoop iron every third course. Cutstone work: Templates under girders and trusses, verandah wall brackets, bases under verandah posts, lintels over ventilators and blocks for door frames. Wood work: One of the timbers mentioned in Circular 2040 C., dated 27th April 1909, as applicable to Table I of Circular, 234 C. of 9th January 1908, should be used. Doors, windows and ventilators: Teak as per list given below:

A:	Door, ⅓ panelled and ⅔ glazed ...	4′-6″ × 8′-6″.
B:	Door, batten	2′-6″ × 6′-6″.
C:	Window, glazed	4′-0″ × 7′-0″.
D:	Window, glazed	3′-0″ × 4′-0″.
E:	Ventilator, glazed with wire netting ...	4′-0″ × 2′-0″.
F:	Screen, door ...	4′-0″ × 8′-0″.

Roofing: The central block will be roofed with Madras terracing with a course of brick on edge, 3 inches concrete, 3 courses of flat tiles, top and bottom, lime plastered. The ward will be roofed with Mangalore tiles over ceiling tiles on teak reepers. Verandahs, bath-rooms and latrines will be roofed with fibro-cement slates on teak reepers. Flooring: With the exception of bath-rooms and latrines, the flooring will consist of any suitable class of patent stone over 4 inches concrete. Bird's Calcutta Indian Patent stone or Bombay Co.'s (Madras) Truscon flooring enamel laid over a coat of cement plaster is recommended. The bath rooms and latrines should be floored with thin Cuddapah slabs pointed with cement or ½ inch Portland cement laid over 4 inches concrete. Cup boards: A cup board lined with galvanised iron sheets riveted together at joints and painted with glossy white washable paint should be provided in the linen room. Finishing: The interior of wards and the surgeon's room and laboratory will be painted with paripan or other suitable washable paint over a coat of Portland cement plaster, ½ inch thick. The interior of bath room and latrine will be rendered with ½ inch Portland cement plaster. The interior of all other rooms and passage will be plastered with 2 coats of lime mortar. The exterior throughout will be plastered 2 coats. Doors, windows and ventilators and iron work will be painted 3 coats of white paint and the roof timbers 2 coats of white paint. Cost: The building shown upon the drawing is estimated to cost from Rs. 23,100 to Rs. 34,700 according to locality.

Abstract Of Quantities For A Main Ward Of 40 Beds (Surgical): Plate 45.

Quantity.	Description of work.
12,616 c. ft. ...	Excavation for foundation.
12,870 " ...	Filling in basement with earth.
6,389 " ...	Concrete, broken brick in lime mortar.
7,666 " ...	Brick in lime mortar (foundation and basement).
10,243 " ...	Brick in lime mortar (superstructure).
526 " ...	Archwork, brick in lime mortar.
137 r. ft. ...	8″ plaster cornice work.
134 c. ft. ...	Cutstone work.
0·98 ton. ...	Rolled steel girders.
0·98 " ...	Hoisting and setting the rolled steel girders.
692 lb. ...	Wrought iron work.
1,062·08 c. ft. ...	Timber, wrought and put up.
96 sq. ft. ...	Barge board, ¾″ thick, including three coats of painting.
383 " ..	Teak doors, ⅓ panel and ⅔ glazed with frames and fittings, complete.
130 " ...	Teak doors, batten with frames and fittings, complete.
1,448 " ...	Teak windows, fully glazed with frames and fittings, complete.
64 " ...	Swing screen doors with frames, etc., complete.
368 " ...	Teak fixed glazed ventilators with perforated zinc sheet between shutters.
1,620 " ...	Terrace roofing with brick on edge, 3″ concrete, 3 courses of flat tiles, top and bottom, lime plastered.
5,312 " ...	Roofing with Mangalore tiles over ceiling tiles with air spaces, complete.
6,280 " ...	Roofing with fibro-cement slates.
8,579 " ...	Levelling course of concrete, 4″ thick.
9,281 " ...	Paving with patent stone.
518 " ...	Rendering with ½″ Portland cement.
8,941 " ...	Plastering with lime mortar, two coats (exterior).
5,483 " ...	Plastering with lime mortar, two coats (interior).
6,025 " ...	Plastering with cement and painting with paripan, interior.
1,019 " ...	Plastering with cement, ½″ thick, interior.
12,194 " ...	Painting, two coats.
2,991 " ...	Painting, three coats.
225 " ...	Brick nogged partitions with frames and fittings, complete.
710 " ...	Brick in cement partition, 4″ thick, reinforced with 2 strips of hoop iron every 3rd course.
21 " ...	Cup-board lined with galvanized iron sheets and painting, complete.
	Contingencies at 5 per cent.
	Petty supervision at 2½ per cent.
	Total Rs. ...

A Main Ward Of 12 Beds: Plate 46.

In the above plate is illustrated the type-design No. 134 issued with proceedings of the Madras Sanitary Board No. 487-S., dated 3-9-1912. The specification report which accompanied this design was as follows: 1. Foundations: A depth of 3 feet is provided, the lower 1 foot 6 inches being concrete of broken brick in lime mortar, and the upper 1 foot 6 inches, brick in lime mortar. The depth and width of foundations will be settled locally according to the nature of the soil. 2. Basement: Brick in lime mortar, 2 feet high. Pressure: The maximum pressure on the soil as drawn is 0·68 ton per square foot. Walling: Walls, archwork and cornice will be built of brick in lime mortar. Internal corners should be rounded. 3. Cut-stone work: Templates under trusses, verandah wall brackets, bases under verandah posts, lintels over ventilators and blocks for door frames. 4. Wood-work: One of the timbers mentioned in Circular No. 2040-C., dated 27th April 1909, as applicable to Table I of Circular No. 234-C., dated 9th January 1908, should be used. 5. Doors, windows and ventilators: Teak as per list given below:

A: Doors, $\frac{1}{3}$ panelled and $\frac{2}{3}$ glazed ... 4′-6″×8′-6″.
B: Doors, battened ... 2′-6″×6′-6″.
C: Windows, fully glazed ... 4′-0″×7′-0″.
D: Windows, fully glazed ... 3′-0″×4′-0″.
E: Ventilators, glazed with wire netting ... 4′-0″×2′-0″.

6. Roofing: The central block will be roofed with Madras terracing with a course of brick on edge, 3 inches concrete, 3 courses of flat tiles, top and bottom, lime plastered. The ward will be roofed with Mangalore tiles over ceiling tiles or with flat and pan tiles on teak reepers. Verandahs, bath rooms and latrines will be roofed with fibro-cement slates, on teak reepers or Mangalore tiles or flat and pan tiles according to locality and cost of materials. 7. Flooring will consist of 2 inches polished Cuddapah or Italian marble slabs, cement pointed, well bedded on 4 inches concrete. The bath room and latrines should be similarly floored with 2 inches Cuddapah slabs pointed with cement on 3 inches concrete or $\frac{1}{2}$ inch Portland cement laid over 4 inches concrete. 8. Cupboards: A cupboard lined with galvanized iron sheets riveted together at joints and painted with glossy white washable paint should be provided in the linen room. 9. Finishing: The interior of wards and the surgeon's room and laboratory will be painted with paripan or other suitable washable paint over a coat of Portland cement plaster, $\frac{1}{2}$ inch thick. The interior of bath room and latrine will be rendered with $\frac{1}{2}$ inch Portland cement plaster. The interior of all other rooms and passage will be plastered with 2 coats of lime mortar and white colour washed. The exterior throughout will be plastered with two coats of lime mortar and white or colour washed as required. Doors, windows, ventilators and iron work will be painted three coats of white paint and the roof timbers, two coats of white paint. 10. Cost: The building shown in the design is estimated to cost from Rs. 9,270 to Rs. 13,905 according to locality.

Abstract Of Quantities For A Main Ward Of 12 Beds: Plate 46.

Quantity.	Description of work.
6,677 c. ft. ...	Excavation for foundation.
5,182 " ...	Filling in basement with earth.
3,368 " ...	Concrete with broken brick in lime mortar.
4,020 " ...	Brick in lime mortar (foundation and basement).
6,125 " ...	Brick in clay (superstructure).
272 " ...	Archwork, brick in lime mortar.
72 r. ft. ...	Plaster cornice work.
58 c. ft. ...	Cutstone work.
208 lbs. ...	Wrought iron work.
446·3 c. ft. ...	Teakwood, wrought and put up.
96 sq. ft. ...	Barge board, $\frac{3}{4}$″ thick, including three coats of painting.
230 " ...	Teak doors, $\frac{1}{3}$ panelled and $\frac{2}{3}$ glazed with frames and fittings, complete.
130 " ...	Teak doors, battened with frames and fittings, complete.
608 " ...	Teak windows, fully glazed with frames and fittings, complete.
112 " ...	Teak fixed glazed ventilators with perforated zinc sheets between them.
688 " ...	Terrace roofing with brick on edge, 3″ concrete, three courses of flat tiles, top and bottom, plastered.
1,728 " ...	Roofing with Mangalore tiles over ceiling tiles with air spaces, complete.
3,307 " ...	Roofing with fibro-cement slates.
3,448 " ...	Levelling course of concrete, 4″ thick.
3,630 " ...	Paving with 2″ Cuddapah slabs or Italian marble.
410 " ...	Rendering with $\frac{1}{2}$″ Portland cement.
5,053 " ...	Plastering with lime mortar, two coats (exterior).
3,283 " ...	Plastering with lime mortar, two coats (interior).
2,933 " ...	Plastering with cement and painting with paripan.
1,019 " ...	Plastering with cement, $\frac{1}{2}$″ thick.
5,126 " ...	Painting, two coats.
1,416 " ...	Painting, three coats.
225 " ...	Brick nogged partitions with frames, etc., complete.
21 " ...	Cupboard lined with galvanized iron sheets including painting.
	Contingencies at 5 per cent.
	Petty supervision at $2\frac{1}{2}$ per cent.
	Total Rs. ...

Special Ward For Indians: Plates 47 and 48.

In the above plate is illustrated the type design No. 118 issued with proceedings of the Madras Sanitary Board, No. 686-S., dated 10-12-1912. The specification report which accompanied this design was as follows: Foundations: A depth of 3 feet is provided, the lower 1 foot 6 inches being concrete broken brick in lime mortar and the upper 1 foot 6 inches, brick in lime mortar. Basement: Brick in lime mortar, 2 feet high. Pressure: The maximum pressure on the soil is 0·76 ton per square foot. Walling: Brick in lime mortar for walls and archwork. Internal corners should be rounded. Cutstone work: Base stones for verandah posts and blocks for door frames. Woodwork: One of the timbers mentioned in Circular No. 2040-C., dated 27th April 1909, as applicable to Table I of Circular No. 234-C of 9th January 1908 should be used. Doors and windows: Teak as per list given below:

A: Door, ⅓ panelled and ⅔ glazed	...	4′-6″×8′-6″.
B: Door, battened and braced	...	2′-6″×6′-6″.
C: Windows, glazed	...	4′-0″×7′-0″.
D: Windows, glazed	...	3′-0″×4′-0″.

Roofing: Mangalore tiles over flat tiles with air spaces. Flooring: The flooring will consist of any suitable kind of patent stone over 4″ concrete. The bath rooms and latrines will be paved with thin Cuddapah slabs pointed with Portland cement or rendered with ½″ Portland cement over 4″ concrete. Finishing: Internal walls of wards will be painted with paripan on a coat of ½″ Portland cement. Internal walls of bath rooms and latrines will be rendered with cement. External walls will be plastered with lime mortar, two coats. Doors and windows will be painted three coats of approved paint and the roof timbers painted, two coats. Cost: The building shown upon the drawings is estimated to cost from Rs. 5,690 to Rs. 8,535 according to locality.

Abstract Of Quantities For A Special Ward For Indians: Plates 47 and 48.

Quantity.		Description of work.
4,762 c. ft.	...	Excavation for foundations.
2,665 „	...	Filling in basement with earth.
2,411 „	...	Concrete, broken brick in lime mortar.
3,167 „	...	Brick in lime mortar (foundation and basement).
3,688 „	...	Brick in lime mortar (superstructure).
199 „	...	Archwork, brick in lime mortar.
11 „	...	Cutstone work.
193·34 „	...	Timber, wrought and put up.
459 sq. ft.	...	Doors, 1/3 panelled and 2/3 glazed with frames, hinges, etc., complete.
195 sq. ft.	...	Doors, battened and braced with frames and hinges complete.
430 „	...	Windows, glazed, with frames, etc., complete.
4,573 „	...	Roofing with Mangalore tiles over flat tiles with air spaces.
1,600 „	...	Levelling course of concrete, 4″ thick.
1,413 „	...	Paving with Indian patent stone.
692 „	...	Rendering with ½″ Portland cement.
2,651 „	...	Plastering with cement and painting with paripan.
7,021 „	...	Plastering with lime mortar, two coats.
1,603 „	...	Painting, three coats.
2,308 „	...	Painting, two coats.
		Contingencies at 5 per cent.
		Petty supervision at 2½ per cent.
		Total Rs. ...

Special Ward For Europeans: Plates 49 and 50.

In the above plates is illustrated the type design No. 119 issued with proceedings of the Madras Sanitary Board, No. 686-S., dated 10-12-1912. The specification report which accompanied this design was as follows: Foundations: A depth of 3 feet is provided, the lower 1 foot 6 inches being concrete of broken brick in lime mortar and the upper 1 foot 6 inches, brick in lime mortar. Basement: Brick in lime mortar, 2 feet high. Pressure: Maximum pressure on the soil at P.P. is 0·54 ton per square foot. Walling: Walls and archwork will be built of brick in lime mortar. Internal corners should be rounded. Cutstone work: Bases under verandah posts, brackets to support verandah wall purlins, lintels over ventilators at gables, sills of doors A, flush with floor and stone to support the chimney shaft. Woodwork: One of the timbers mentioned in Circular No. 2040-C of 27th April 1909 as applicable to Table 1 of Circular No. 234-C of 9th January 1908 should be used. Doors, windows and ventilators: Teak as per list given below:

A: Door, ⅓ panelled and ⅔ glazed		4′—6″×8′—6″.
B: Door, batten	...	3′—0″×6′—6″.
C: Window, glazed	...	4′—0″×5′—0″.
D: Window, frosted glass	...	5′—0″×4′—0″.
E: Window, batten	...	3′—0″×4′—0″.
F: Ventilators, glazed with perforated zinc sheets	...	4′—0″×1′—6″.

Roofing: With the exception of the roof over ward, cover the roof with fibro-cement slates on teak reepers. Wards will be roofed with Mangalore tiles over ceiling tiles: Flooring: With the exception of bath rooms and kitchen, the flooring will consist of any suitable kind of patent stone over 4″ concrete. The bath rooms and kitchen will be paved with thin Cuddapah slabs pointed with cement or

rendered with $\frac{1}{2}''$ Portland cement over 4″ concrete. Finishing: The interior of wards will be painted with paripan or other glossy white washable paint on a coat of cement plaster, $\frac{1}{2}''$ thick and that of bath room will be plastered with Portland cement plaster only. The kitchen will be plastered with two coats of lime mortar. The exterior throughout will be plastered with lime plaster. All doors, windows and ventilators will receive three coats of approved paint and the roof timbers, two coats of approved colour. Cost: The building shown upon the drawings is estimated to cost from Rs. 5,660 to Rs. 8,500 according to locality.

Abstract Of Quantities For A Special Ward For Europeans: Plates 49 and 50.

Quantity.	Description of work.
3,825 c. ft. ...	Excavation for foundations.
2,852 „ ...	Filling in basement with earth.
1,937 „ ...	Concrete, broken brick in lime mortar.
2,409 „ ...	Brick in lime mortar (foundation and basement).
2,319 „ ...	Brick in lime mortar (superstructure).
16 „ ...	Archwork, brick in lime mortar, semi-circular.
106 „ ...	Archwork, brick in lime mortar, segmental.
44 „ ...	Cutstone work.
90 lbs. ...	Wrought iron work.
264·05 c. ft. ...	Timber, wrought and put up.
106 sq. ft. ...	Teak barge board including two coats of painting.
153 „ ...	Teak doors, 1/3 panelled and 2/3 glazed including frames and iron fittings, complete.
59 „ ...	Teak batten doors with frames and iron fittings, complete.
120 „ ...	Teak glazed windows with frames and iron fittings, complete.
40 „ ...	Teak windows, frosted glass including frames and iron fittings, complete.
24 „ ...	Teak batten windows with frames and iron fittings complete.
60 „ ...	Teak ventilators with fixed glazed shutters and perforated zinc sheet between them.
891 „ ...	Roofing with Mangalore tiles over ceiling tiles.
2,351 „ ...	Roofing with fibro-cement slates.
1,786 „ ...	Levelling course of concrete, 4″ thick, under flooring.
1,806 „ ...	Paving with patent stone.
329 „ ...	Rendering with $\frac{1}{2}''$ Portland cement.
1,831 „ ...	Plastering with cement, $\frac{1}{2}''$ thick; and painting with paripan.
614 „ ...	Cement plastering, $\frac{1}{2}''$ thick.
580 „ ...	Plastering with lime mortar, two coats (inside).
3,056 „ ...	Plastering with lime mortar, two coats.
674 „ ...	Painting, three coats.
2,848 „ ...	Painting, two coats.
	Finishing chimney.
	Constructing cooking range, complete.
144 sq. ft. ...	Zinc sheet for valleys.
16 „ ...	Cupboard with necessary frames and fittings.
	Contingencies at 5 per cent.
	Petty supervision at $2\frac{1}{2}$ per cent.
	Total Rs.

Special Ward For A Larger Hospital: Plates 51 And 52.

In the above plates is illustrated the type design No. 120 C issued with proceedings of the Madras Sanitary Board, No. 686-S., dated 10-12-1912. The specification report which accompanied this design was as follows: Foundations: A depth of 3 feet is provided, the lower 1 foot 6 inches being concrete of broken brick in lime mortar and the upper 1 foot 6 inches, brick in lime mortar. Basement: Brick in lime mortar, 2 feet high. Pressure: Maximum pressure on the soil is ·50 ton per square foot. Walling: Walls and arches will be built of brick in lime mortar. Internal corners should be rounded. Cutstone work: Bed stones under trusses, base stones of verandah posts, corbel to verandah wall purlins, sill stones of doorways flush with the floor. Woodwork: One of the timbers mentioned in Circular No. 2040 C., dated 27th April 1909, as applicable to Table I of Circular No. 234 C., dated 9th January 1908, should be used. Doors, windows and ventilators: Teak as per list given below:

A: Door, $\frac{1}{3}$ panelled and $\frac{2}{3}$ glazed ... 4′-6″×8′-6″.
B: Door, teak battened ... 3′-0″×6′-6″.
C: Window, glazed ... ... 4′-0″×5′ 0″.
D: Window, frosted glass ... 5′-0″×4′-0″.
E: Window, teak battened ... 3′-0″×4′-0″.
F: Ventilator, with fixed glazed shutters and perforated zinc sheet between them ... 4′-0″×1′-6″.

Roofing: Mangalore tiles over ceiling tiles with air spaces on teak reepers for wards of single and four beds. Fibro-cement slates on teak reepers for verandahs, kitchen and bath rooms. Flooring: Pave the floor of wards, verandahs and passages with any suitable class of patent stone on 4 inches concrete. The floors of bath room and kitchen will be paved with thin stone slabs on 4 inches concrete and pointed with Portland cement. Finishing: The internal walls of wards will be rendered with cement and painted over with "paripan" or other suitable white glossy washable paint. The interior of bath rooms will be rendered with $\frac{1}{2}$ inch cement. The interior of kitchen will be plastered with lime mortar, two coats. The

exterior throughout will be plastered. All doors, windows and ventilators will be painted with three coats of approved colour and the roof timbers with two coats of approved paint. Cost: The buildings shown upon the drawings is estimated to cost from Rs. 7,860 to Rs. 11,800 according to locality.

Abstract Of Quantities For A Special Ward For A Larger Hospital: Plates 51 And 52.

Quantity.	Description of work.
5,144 c. ft.	Excavation for foundations.
4,011 „	Filling in basement with earth.
2,517 „	Concrete, broken brick in lime mortar.
3,313 „	Brick in lime mortar (foundation and basement).
4,030 „	Brick in lime mortar (superstructure).
149 „	Archwork, brick in lime mortar.
51 „	Cutstone work.
167 lb.	Wrought iron work.
43·64 c. ft.	Timber, wrought and put up.
106 sq. ft.	Plain barge board including two coats of painting.
10 r. ft.	Wooden shelves, 1' 6" wide, 1" thick, supported on brackets.
230 sq. ft.	Teak doors, ⅓ panelled and ⅔ glazed including frames and iron fittings complete.
59 „	Teak battened doors with frames and iron fittings complete.
160 „	Teak glazed windows with frames and iron fittings complete.
40 „	Teak windows with frosted glass including frames and iron fittings complete.
24 „	Teak battened windows with frames and iron fittings complete.
96 „	Teak ventilator with fixed glazed shutters and perforated zinc sheet between them.
1,654 „	Roofing with Mangalore tiles over ceiling tiles with air spaces.
3,006 „	Roofing with fibro-cement slates.
2,673 „	Levelling course of concrete, 4" thick.
2,801 „	Paving with patent stone.
453 „	Paving with thin stone slabs and pointing with Portland cement.
4,162 „	Plastering with lime mortar, two coats.
3,242 „	Plastering with cement, ½" thick and painting with paripan.
588 „	Plastering with ½" cement.
1,113 „	Painting, three coats.
3,942 „	Painting, two coats.
L.S.	Constructing oven in kitchen.
	Contingencies at 5 per cent.
	Petty supervision at 2½ per cent.
	Total Rs.

Maternity Ward: Plates 53 And 54.

In the above plates is illustrated the type design No. 121 issued with proceedings of the Madras Sanitary Board, No. 686-S., dated 10-12-1912. The specification report which accompanied this design was as follows: Foundations: A depth of 3 feet is provided, the lower 1 foot 6 inches being concrete of broken brick in lime mortar and the upper 1 foot 6 inches, brick in lime mortar. Basement: Brick in lime mortar, 2 feet high. Pressure: Maximum pressure on the soil in front wall of the ward is 0·51 ton per square foot. Walling: Walls and archwork will be built of brick in lime mortar. Internal corners should be rounded. Cutstone work: Templates under trusses, bases of verandah posts, corbels to support verandah wall purlins, bed plates under lintels over windows H, and blocks for door frames. Woodwork: One of the timbers mentioned in Circular No. 2040 C. of 27th April 1909 as applicable to Table I of Circular No. 234-C. of 9th January 1908 should be used. Doors, windows and ventilators: Teak as per list given below:

A:	Door, ⅓ panelled, ⅔ glazed ...	4'-6"×8'-0".
A¹:	Door, panelled	4'-6"×8'-0".
B:	Door, ⅓ panelled, ⅔ glazed ...	4'-0"×8'-0".
C:	Door, panelled	4'-0"×8'-0".
D:	Door, battened	3'-0"×7'-0".
E:	Window, glazed	4'-0"×7'-0".
F:	Window, inside glazed, outside venetianed ...	4'-0"×7'-0".
G:	Window, glazed	3'-0"×4'-0".
H:	Window, glazed	7'-0"×6'-0".
J:	Ventilator, glazed with perforated zinc sheets ...	1'-6"×3'-6".

Roofing: Mangalore tiles over flat tiles with air spaces, on teak reepers for delivery ward, main ward, ward kitchen, nurses room, nurses linen and store room and septic ward. Fibro-cement slates on teak reepers for verandahs, covered passage, latrine and bath room. Flooring: With the exception of bath rooms and latrines, the flooring will consist of any suitable class of patent stone over 4" concrete. Birds Calcutta Indian patent stone, or Bombay Co.'s (Madras) Truscon flooring enamel laid over a coat of cement plaster, is recommended. The bath rooms and latrines should be floored with thin Cuddapah slabs pointed with cement, or ½" Portland cement laid over 4" concrete. Finishing: The interior of main ward, delivery ward and septic ward will be painted with paripan "glossy" or other "glossy" white washable paint on a coat of Portland cement plaster, ½" thick. The interior of all other rooms and the exterior throughout will be plastered with two coats of lime mortar. All doors, windows and ventilators will be painted with three coats of approved colour and the roof timbers with two coats of approved paint. Cost: The building shown upon the drawings is estimated to cost from Rs. 8,460 to Rs. 12,700 according to locality.

Abstract Of Quantities For A Maternity Ward: Plates 53 And 54.

Quantity.	Description of work.
5,349 c. ft. ...	Excavation for foundations.
3,730 „ ...	Filling in basement with earth.
2,696 „ ...	Concrete, broken brick in lime mortar.
3,254 „ ...	Brick in lime mortar (foundation and basement).
4,325 „ ...	Brick in lime mortar (superstructure).
178 „ ...	Archwork, brick in lime mortar.
30 „ ...	Cutstone work.
0·18 ton. ...	Rolled steel joists.
78 lb. ...	Wrought iron work.
358·48 c. ft. ...	Timber, wrought and put up.
58 sq. ft. ...	Weather boarding with 3 coats of painting.
116 „ ...	Barge boarding with 3 coats of painting.
208 „ ...	Doors, ½ panelled and ½ glazed with frames and fittings, complete.
104 „ ...	Doors, panelled with frames and fittings, complete.
84 „ ...	Doors, battened with frames and fittings, complete.
468 „ ...	Windows, glazed with frames and fittings, complete.
56 „ ...	Windows, inside glazed and outside venetianed with frames and fittings, complete.
53 „ ...	Ventilators, glazed with perforated zinc sheets between them.
2,375 „ ...	Roofing with Mangalore tiles over flat tiles, air-spaced, including teak reepers, complete.
2,083 „ ...	Roofing with fibro-cement slates including reepers, etc.
2,533 „ ...	Levelling course of concrete, 4" thick.
2,832 „ ...	Paving with patent stones.
181 „ ...	Rendering with Portland cement, ¾" thick.
6,104 „ ...	Plastering with lime mortar, 2 coats.
2,633 „ ...	Plastering with cement and painting with paripan, 2 coats.
1,521 „ ...	Painting, 3 coats.
4,161 „ ...	Painting, 2 coats.
583 „ ...	Ferro-concrete partition with necessary doors, etc., complete.
60 „ ...	Screens with necessary frames, etc., complete.
35 „ ...	Cupboards.
	Contingencies at 5 per cent. ...
	Petty supervision at 2½ per cent. ...
	Total Rs. ...

A Phthisis Ward For 12 Beds: Plates 55 And 56.

In the above plates are illustrated the type designs Nos. 142 and 143 issued with proceedings of the Madras Sanitary Board, No. 243-S., dated 9-4-1913. The specification report which accompanied these designs was as follows: Foundations: A depth of 3 feet is provided in the quantities, the lower 1 foot 6 inches being concrete, broken brick in lime mortar and the upper 1 foot 6 inches, brick in lime mortar. The required depth and width will be settled locally according to the nature of the soil. Basement will consist of brick in lime mortar 3 feet high for ward and 2 feet 6 inches high for passage, bath room and latrine. Superstructure: The walls of bath room and latrine and the piers of the ward will be of brick in lime mortar. All corners should be rounded. Between the piers all round there will be movable shutters in 3 parts, as shown in detail in plate 56. (*a*) The bottom (2′ 6″) will be of "Lammit" or similar sheets secured to teak frames and the shutters will be hinged at bottom so as to open outwards and lie flat against the plinth where they will be secured by a button. (*b*) The large middle shutters will be similar sheets revolving on side pivots with wires and brass rings for fixing on to brass pegs so as to hold them open at different angles. (*c*) The top will consist of glass shutters, swinging on side pivots, and similarly regulated by means of wires, brass rings and pegs. Stone work: Base stones under verandah posts and templates under bearings of girders will be of dressed cutstone. The steps will be paved with Cuddapah or other stone slabs set in lime mortar, and pointed with Portland cement; or they may be stone if procurable without great expense. Doors and windows will be of teak as per description given below:

A:	Door, braced and battened	...	3′-0″×6′-6″.
B:	Door, do.	...	2′-6″×6′-6″.
C:	Window, glazed	...	3′-0″×4′-0″.
D:	Door, ½ panelled and ½ glazed	...	5′-0″×8′-0″.

Wood work: The type schedule provides for one of the timbers mentioned in the Chief Engineer's Circular Memorandum No. 2040-C., dated 27th April 1909, as applicable to Table I of Circular Memorandum No. 234-C., dated 9th January 1908. Roofing: The roof of the ward will be Madras terrace with a projection of about 4 feet all round to shade the clerestory basements. The roof over bath room and latrine will be of plain Mangalore tiles on teak reepers, and that over passage, fibro-cement slates on teak reepers. Flooring of ward will be any suitable class of patent stone or cement rendering, ¾″ thick, over 4″ concrete, the floor being highest in the middle with slight fall towards channels along outside walls with rounded corners. The floor of passage, bath room and latrine will be rendered with ¾″ cement over 4″ concrete. Finishing: The exterior of basement, and the interior and exterior of walls and piers in superstructure will be plastered with lime mortar, 2 coats, with the exception of internal walls of bath room and latrine which will be rendered with cement to a height of 5 feet from the floor. The doors, windows and clerestory windows will be painted three coats of glossy washable paint and roof timbers,

two coats. The Lammit panels will be painted with waterproof paint. Cost: The cost of the building shown in the drawings varies from Rs. 6,000 to Rs. 9,000 according to locality.

Abstract Of Quantities For A Phthisis Ward For 12 Beds: Plates 55 And 56.

Quantity.		Description of work.
2,334 c. ft.	...	Excavation for foundations.
3,183 „	...	Filling in basement with earth.
1,190 „	...	Concrete, broken brick in lime mortar.
1,561 „	...	Brick in lime mortar (foundations and basement).
1,575 „	...	Brick in lime mortar (superstructure).
37 „	...	Archwork, brick in lime mortar.
84 sq. ft	...	Partition, $4\frac{1}{2}''$ thick, brick in cement mortar, reinforced with two strings of hoop iron every third course.
33 c. ft.	...	Cutstone work.
2·93 tons.	...	Rolled steel joists.
2·93 „	...	Hoisting and setting the rolled steel joists.
7 lbs.	...	Wrought iron work.
237·60 c. ft.	...	Timber, wrought and put up.
22 sq. ft	...	Barge board, $\frac{3}{4}''$ thick, including three coats of painting.
72 „	...	Doors, braced and battened with frames and fittings complete.
80 „	...	Doors, $\frac{1}{3}$ panelled and $\frac{2}{3}$ glazed with frames and iron fittings complete.
24 „	...	Windows, glazed with frames and iron fittings complete.
1,278 „	...	Movable shutters, $\frac{1}{3}$ glazed and $\frac{2}{3}$ lammit panel including frames and fittings complete.
1,691 „	...	Terracing with brick on edge, 3" concrete, three courses of flat tiles, top and bottom, lime plastered.
328 „	...	Roofing with plain Mangalore tiles including teak reepers complete.
369 „	...	Roofing with fibro-cement slates on teak reepers including fixing complete.
1,268 „	...	Levelling course of concrete, 4" thick.
1,010 „	...	Paving with patent stone.
384 „	...	Rendering with $\frac{3}{4}''$ Portland cement.
63 „	...	Paving with Cuddapah slab set in mortar and pointed with Portland cement.
3,628 „	...	Plastering with lime mortar, two coats.
292 „	...	Rendering with $\frac{1}{2}''$ Portland cement.
1,602 „	...	Painting, three coats, of glossy washable paint.
2,512 „	...	Painting, two coats.
900 „	...	Painting with water-proof paint.
155 r. ft.	...	Masonry drain all round the building.
Nos. 2	...	Buckets for receiving the sullage water.
	...	Zinc spouts.
		Contingencies at 5 per cent.
		Petty supervision at $2\frac{1}{2}$ per cent.
		Total Rs. ...

Contagious Diseases, Isolation Or Cholera Ward: Plates 57 And 58.

In the above plates is illustrated the type design No. 165 issued with proceedings of the Madras Sanitary Board, No. 93-S., dated 4-2-1915, and 847-S., dated 12-11-1915. The specification report which accompanied this design was as follows: Foundations: A depth of 3 feet is provided, the lower 1′ 6″ being concrete of broken brick in lime mortar and the upper 1′ 6″, brick in lime mortar. The depth of foundations will be settled locally according to the nature of the soil. Basement: Brick in lime mortar, 2 feet high. Walling: The walls and partitions will be brick nogged in lime mortar. Galvanized wire netting will be provided on top of main walls to allow free ventilation. Stonework: Bases of verandah posts will be of cut stone. Doors and windows: These will be as per description given below:

A: Doors, $\frac{1}{3}$ panelled and $\frac{2}{3}$ glazed	...	4′-0″ × 7′-6″.
B: Doors, battened	... ...	4′-0″ × 6′-6″.
C: Doors, battened	... ...	2′-6″ × 6′-6″.
D: Windows, glazed	... ...	4′-0″ × 5′-0″.
E: Windows, glazed	... ...	3′-0″ × 4′-0″.

Woodwork: The door and window shutters will be of teak wood and all woodwork will be of country wood. Roofing: The roof will be of flat and pan tiles over teak reepers with chunam borders, etc. Flooring: The floors will be of $\frac{1}{2}''$ cement plaster over 4″ concrete bed. Finishing: The basement and steps will be plastered with Portland cement and the walls with lime mortar, two coats. All the woodwork including doors and windows will be painted with solignum. Cost: The building is estimated to cost from Rs. 3,300 to Rs. 4,950 according to locality. Note: If only 4 beds are required, each ward should be made 8′ 6″ shorter.

Abstract Of Quantities For A Contagious Diseases, Isolation Or Cholera Ward: Plates 57 And 58.

Quantity.		Description of work.
2,573 c. ft.	...	Excavation for foundations.
2,635 „	...	Filling in basement with earth.
1,301 „	...	Concrete, broken brick in lime mortar.
1,591 „	...	Brick in lime mortar, foundations and basement.
440 „	...	Brick nogged wall in mortar.
2 „	...	Cutstone blocks.
120 sq. ft.	...	Teak doors, 1/3 panelled and 2/3 glazed with fastenings, etc., complete.
85 „	...	Teak doors, battened do.
264 „	...	Teak windows, glazed shutters, complete.
120 „	...	Galvanized swing shutters.
1,581 „	...	Levelling course of concrete, 4" thick.
2,383 „	...	Rendering with Portland cement, $\frac{1}{2}''$ thick.
2,857 „	...	Roofing with flat and pan tiles over teak reepers including lime mortar borders, etc., complete.

Quantity.	Description of work.
303 lbs. ..	Wrought iron work.
376·11 c. ft. ..	Country wood, wrought and put up.
4,375 sq. ft. ..	Painting with solignum.
2,344 „ ..	Plastering with lime mortar, two coats.
394 sq. ft. ...	Galvanized wire netting with necessary frames including painting, etc., complete.
	Contingencies at 5 per cent.
	Petty supervision at 2½ per cent.
	Total Rs.

An Operation Theatre: Plates 59, 60 And 61.

In the above plates are illustrated the type designs Nos. 123 and 124 issued with proceedings of the Madras Sanitary Board, No. 686-S, dated 10—12—1912 and No. 770-S, dated 21—8—1914. The specification report which accompanied these designs was as follows: Foundations: A depth of 3 feet is provided, the lower 1 foot 6 inches being concrete of broken brick in lime mortar and the upper 1 foot 6 inches will be brick in lime mortar. Basement: Brick in lime mortar, 2 feet high. Pressure: Maximum pressure on the soil will be ·74 ton per square foot. Walling: Walls and arches will be built of brick in lime mortar. Internal corners should be rounded. Cutstone work: Bed stone under girders, base stones of verandah posts, blocks for door frames and corbels of verandah wall purlins. Woodwork: One of the timbers mentioned in Circular No. 2040-C. of 27th April 1909, as applicable to Table 1 of Circular No. 234-C. of 9th January 1908, should be used. Doors and windows: Teak as per references given below:

A: Door, ⅓ panelled ⅔ glazed ... 4′-6″ × 8′-6″.
B: Single leaf door, ⅔ glazed with foot lever ... ... 4′-6″ × 8′-6″.
C: Single leaf door, panelled ... 4′-6″ × 8′-6″.
D: Door, battened ... ... 3′-0″ × 6′-6″.
E: Window, glazed ... ... 4′-0″ × 7′-0″.
F: Window, glazed ... ... 10′-0″ × 9′-6″.
G: Window, glazed ... ... 7′-0″ × 9′-6″.
H: Ticket window, panelled shutter. 2′-4½″ × 2′-0″.
I: Almyrah, panelled shutter ... 3′-6″ × 7′-0″.
J: Window, glazed ... ... 3′-0″ × 4′-0″.

Roofing: With the exception of roofs over operation, sterilising, anæsthetic and surgeon's preparation rooms, cover the roofs with fibro-cement slates. Construct the roofs of the above mentioned rooms with jack-arched terrace supported on rolled steel joists. Flooring: The floors of main rooms and verandahs will consist of any suitable kind of patent stone over 4″ concrete. The bath room will be paved with thin Cuddapah slabs pointed with Portland cement or rendered with ½″ Portland cement over 4″ concrete. Finishing: The interior of main rooms will be plastered with cement and painted two coats of paripan or other suitable white washable paint. The interior of bath room will be rendered with Portland cement to a height of 3 feet and above that, plastered with lime mortar, two coats. The exterior throughout will be plastered. All doors and windows will be painted three coats of approved colour and roof timbers, two coats of approved paint. The window facing the operation table must face north. Cost: The building shown upon the drawings is estimated to cost from Rs. 4,800 to Rs. 7,200 according to locality. A single leaf door, panelled, as per type design No. 124 shewn in plate 61 should be inserted between the sterilising room and the surgeon's preparation room shown on the Sanitary Board's type design No. 123 shown in plates 59 and 60.

Abstract Of Quantities For An Operation Theatre: Plates 59, 60 And 61.

Quantity.	Description of work.
3,069 c. ft. ...	Excavation for foundations.
1,383 „ ...	Filling in basement with earth.
1,532 „ ...	Concrete, broken brick in lime mortar.
1,930 „ ...	Brick in lime mortar (foundation and basement.)
3,131 „ ...	Brick in lime mortar (superstructure).
144 „ ...	Archwork, brick in lime mortar.
120 r. ft. ...	Cornice, brick in lime mortar.
37 c. ft. ...	Cutstone work.
107·57 c. ft....	Timber, wrought and put up.
22 sq. ft. ...	Plain wooden barge board including two coats of painting.
38 „ ...	Teak doors, ⅓ panelled and ⅔ glazed with parliamentary hinges and without sills including frames and iron fittings complete.
38 „ ...	Teak single leaf door, ⅓ panelled and ⅔ glazed fitted with foot lever and parliamentary hinges and without sills including frames and iron fittings, etc., complete.
77 „ ...	Teak panelled single leaf doors with foot lever, parliamentary hinges and without sills including frames and iron fittings, complete.
32 „ ...	Teak batten doors with frames and iron fittings, complete.
124 „ ...	Teak glazed window with frames and iron fittings, complete.
162 „ ...	Teak glazed windows with frames and iron fittings, complete, big size.
5 „ ...	Teak ticket window.
74 „ ...	Teak almyrahs with panelled shutters including frames and iron fittings, complete.
1·93 tons...	Rolled steel girder.
1·93 „ ...	Hoisting and setting girders.
359 lb. ...	Wrought iron work.
730 sq. ft. ...	Jack-arched roofing.
1,413 „ ...	Roofing with fibro-cement slates.
922 sq. ft. ...	Levelling course of concrete, 4″ thick.
1,548 „ ...	Paving with Indian patent stones set in cement.

Quantity.	Description of work.
79 sq. ft. ...	Paving with Cuddapah slabs over ½" mortar and pointing with Portland cement.
381 „ ...	Plastering with cement and painting with paripan.
87 „ ...	Plastering with cement, ½" thick.
212 „ ...	Plastering with lime mortar, two coats.
2,977 „ ...	Plastering with lime mortar, two coats, (exterior).
867 „ ...	Painting, three coats.
1,258 „ ...	Painting, two coats.
	Contingencies at 5 per cent.
	Petty supervision at 2½ per cent.
	Total Rs.

Out-Patient Dispensary For Women And Children: Plates 63 And 64.

In the above plates is illustrated the type design No. 140 issued with proceedings of the Madras Sanitary Board, No. 1-S., dated 2-1-1913. The specification report which accompanied this design was as follows: Foundations: A depth of 3 feet is provided, the lower 1 foot 6 inches being concrete of broken brick in lime mortar and the upper 1 foot 6 inches, brick in lime mortar. Basement: Brick in lime mortar, 2′ 0″ high. Pressure: Maximum pressure on the soil is 0·69 ton per square foot. Walling: Walls, archwork, columns and cornice will be built of brick in lime mortar. Internal corners should be rounded. Cutstone work: Templates under girders, bases of verandah posts, corbels to support verandah wall purlins, sills of doors and lintels over ventilators. Woodwork: One of the timbers mentioned in the Chief Engineer's Circular No. 2040-C., dated 27th April 1909, as applicable to Table I of Circular No. 234-C, dated 9th January 1908, should be used. Doors, windows and ventilators: Teak as per list given below:

A : Door, ⅓ panelled and ⅔ glazed ... 4′-0″×8′-0″.
B : Single leaf door, panelled ... 4′-0″×8′-0″.
C : Do. do. ... 3′-6″×7′-0″.
D : Window, glazed pivoted top and bottom ... 4′-0″×5′-0″.
E : Window, venetianed with iron bars 3′-6″×5′-0″.
F : Window, glazed ... 6′-0″×6′-0″.
G : Single leaf door, ⅓ panelled and ⅔ glazed ... 4′-6″×8′-6″.
H : Door, braced and battened ... 3′-0″×6′-6″.
K : Door, braced and battened ... 2′-6″×6′-6″.
L : Window, frosted glass ... 3′-0″×4′-0″.
M : Ventilator, with fixed glazed shutters and perforated zinc sheet between ... 4′-0″×1′-6″.

Roofing: With the exception of the roof over latrine, verandah and passage, cover the roof with Madras terracing with brick on edge, 3 inches concrete, three courses of flat tiles, top and bottom, lime plastered. The latrine, verandah and passage will be roofed with fibro-cement slates on teak reepers. In localities where the rainfall is heavy, a verandah roof consisting of glazed Mangalore tiles should be provided on the north side of the examination room. Flooring: With the exception of the latrine, the floors will consist of any suitable class of patent stone on 4″ concrete. The latrine will be paved with thin stone slabs on 4″ concrete and pointed with Portland cement. Finishing: The interior of examination room and dressing room will be painted with paripan or other suitable white glossy washable paint on a coat of Portland cement, ½″ thick. The interior of all other rooms excepting the latrine will be plastered with two coats of lime mortar. The interior of latrine will be plastered with Portland cement. The exterior throughout will be plastered with lime mortar. All doors, windows, ventilators and girders will be painted three coats of approved paint and the roof timbers painted, two coats. Cost: The building shown upon the drawings is estimated to cost from Rs. 5,400 to Rs. 8,100 according to locality. Note: The position which the operation room should occupy, if required, is indicated by dotted lines on the plan. It is not provided for in the quantities.

Abstract Of Quantities For An Out-Patient Dispensary For Women And Children: Plates 63 And 64.

Quantity.	Description of work.
4,014 c.ft. ...	Excavation for foundations.
2,280 „ ...	Filling in basement with earth.
2,062 „ ...	Concrete, broken brick in lime mortar.
2,547 „ ...	Brick in lime mortar (foundations and basement).
3,848 „ ...	Brick in lime mortar (superstructure).
27 r.ft. ...	Brick columns, 1′ 3″ diameter, in lime mortar with base, capital and bond stones including plastering, complete.
109 c.ft. ...	Archwork, brick in lime mortar.
168 r.ft. ...	Cornice, brick in lime mortar, projecting 5″, including plastering.
74 c.ft. ...	Cutstone work.
0·49 ton ...	Rolled steel joists.
0·49 „ ...	Hoisting and setting the joists.
55 lbs. ...	Wrought iron work.
169·80 c.ft. ...	Timber, wrought and put up.
32 sq. ft. ...	Wooden barrier including painting, complete.
128 „ ...	Doors, ⅓ panelled and ⅔ glazed with frames and iron fittings, complete.
57 „ ...	Single leaf door, panelled with frames and iron fittings, complete.
36 „ ...	Doors, braced and battened with frames and fittings, complete.

Quantity.	Description of work.
40 sq. ft. ...	Windows, glazed, pivoted top and bottom including frames and fittings, complete.
35 „ ...	Windows, venetianed with iron bars including frames and fittings, complete.
36 „ ...	Windows, glazed with iron casements.
12 „ ...	Windows, with frosted glass shutters, including frames and fittings, complete.
36 „ ...	Ventilators with fixed glazed shutters and perforated zinc sheet between them.
665 „ ...	Madras terrace roofing.
1,360 „ ...	Roofing with fibro-cement slates including teak reepers, complete.
1,401 „ ...	Levelling course of concrete, 4" thick.
1,666 „ ...	Paving with patent stone.
170 „ ...	Paving with thin stone slabs and pointing with Portland cement.
1,396 „ ...	Plastering with cement, ½" thick and painting with paripan.
299 „ ...	Plastering with Portland cement, ½" thick.
4,694 „ ...	Plastering with lime mortar, two coats.
843 „ ...	Painting, three coats.
1,823 „ ...	Painting, two coats.
No. 2. ...	Ticket windows including counters, frames, fittings and wood oiling, complete.
71 sq. ft. ...	Cuddapah slab shelves including wooden brackets and painting, complete.
33 „ ...	Lead sheets for valleys.
	Contingencies at 5 per cent.
	Petty supervision at 2½ per cent.
	Total Rs. ...

A Kitchen And Store Room For Dispensary: Plate 66.

In the above plate is illustrated the type design No. 148-B issued with proceedings of the Madras Sanitary Board, No. 918-S., dated 19-12-1913. The specification report which accompanied this design was as follows: Foundations: A depth of 3 feet is provided in the quantities, the lower 1 foot 6 inches being concrete of broken brick in lime mortar and the upper 1 foot 6 inches being of brick in lime mortar. The required depth and width will be settled locally according to the nature of the soil. Walling: Construct the walls of ground mould brick in lime mortar, in English bond according to the thicknesses shown upon the drawing. Stonework: Dressed base stones 10" × 10" × 5" are provided under the verandah posts. Form mortice holes 2" square and 3" deep in these stones to receive tenons worked on the solid of the posts. Construct the steps of brick in lime mortar rendered with cement or they may be of stone, if procurable without great expense; otherwise construct them of clinker brick on edge, or of brick rendered with Portland cement, or of 6" × 6" tiles laid in Portland cement at the discretion of the Executive Engineer. Woodwork: The scantlings provided in the quantities for the timber throughout are suited to well seasoned Erool (*xylia dolabriformis*) or Pillaimarudu (*terminalia paniculata*). All timber should be free from shakes and other defects and sawn die square. Verandah posts may be of stone, if procurable at reasonable rates. Doors, windows and ventilators: The styles of the doors and windows shall be not less than 1½" thick. Doors and windows shall be in accordance with the lettered description given below:

A: Doors, battened ... ... 3'-6"×7'-0".
B: Windows, battened with iron bars 3'-0"×4'-0".

Roofs: Cover the roof with Mangalore tiles imbedded in mortar over flat tiles. Flooring: Pave the floor with 4" concrete rendered with Portland cement, ½" thick. Where the soil is damp, the filling below the flooring should be river sand, gravel or brick rubble. Finishing: Cover the interior and exterior walls with one coat of lime plaster and two coats of whitewash. Where good stone is available, the exterior should be flush pointed with lime mortar. Paint the roof timbers, doors, and windows with two coats of approved colour. Where woodwork is exposed to weather, lead paint shall be used instead of zinc paint. Cost: The building shown upon the drawing is estimated to cost from Rs. 900 to Rs. 1,350 according to locality.

Abstract Of Quantities For A Kitchen And Store Room For Dispensary: Plate 66.

Quantity.	Description of work.
734 c. ft. ...	Excavation for foundations.
416 „ ...	Filling in basement with earth.
377 „ ...	Concrete, broken brick in lime mortar
586 „ ...	Brick in lime mortar, foundation and basement.
714 „ ...	Brick in lime mortar, superstructure.
20 „ ...	Archwork, brick in lime mortar.
2 „ ..	Cutstone.
42·27 c. ft. ...	Timber, wrought and put up.
33 sq. ft. ...	Barge board, ¾" thick, including painting complete.
49 „ ...	Doors, battened with frames and fittings complete.
27 „ ...	Windows, battened with iron bars, frames and fittings complete.
599 „ ...	Roofing with Mangalore tiles imbedded in mortar over flat tiles including teak reepers complete.
249 „ ...	Levelling course of concrete, 4" thick.
359 „ ...	Rendering with Portland cement, ½" thick.
1,807 „ ..	Plastering with lime mortar, one coat including two coats of white wash.
700 „ ...	Painting, two coats.
	Contingencies at 5 per cent.
	Petty supervision at 2½ per cent.
	Total Rs. ...

An Out-Patient Dispensary: Plates 67, 68, 69 And 70.

In the above plates are illustrated the type designs Nos. 158, 158-A and 158-B issued with proceedings of the Madras Sanitary Board, No. 609-S., dated 6-7-1914. The specification report which accompanied these designs was as follows: Foundations: A depth of 4 feet is provided in the quantities, the lower 2 feet being concrete of broken brick in lime mortar and the upper two feet, brick in lime mortar. The required depth and width will be settled locally according to the nature of the soil. Basement: Brick in lime mortar, 2 feet high. Walling: Construct the walls of brick in lime mortar, in English bond according to the thicknesses shown upon the drawings. Internal corners should be rounded. Stonework: Place dressed templates under the bearings of all girders and sills of doors flush with floor. Construct the steps of brick in lime mortar and pave the treads with stone slabs pointed with Portland cement, or they may be of stone, if procurable without great expense; otherwise construct them of clinker brick on edge, or of brick rendered with Portland cement or of 6"×6" tiles laid in Portland cement at the discretion of the Executive Engineer. Woodwork: The scantlings provided in the quantities for the timber throughout are suited to well seasoned teakwood, sal, ainee (artocarpus hirsuta), karamarudu (terminalia tomentosa) irumbogum (hopea parviflora) or Australian jarrah, blackbutt or tallow wood. Erool (xylia dolabriformis) or pillaimarudu (terminalia paniculata) may be used with increase to size of scantlings as per Table II of Circular No. 234-C., dated 9th January, 1908. All timber should be free from shakes and other defects and sawn die square. Doors, windows and ventilators: The styles of the doors and windows shall be not less than 1½" thick. Doors and windows shall be of teak and shall be in accordance with the lettered description given below:

D: Door, panelled (not raised panels) 4'-6"×8'-6".
T: Window, sliding shutters ... 1'-10½"×1'-6".
Y: Window, U. S. sash ... 6'-1$\frac{13}{16}$"×6'-3⅛".
W: Window, glazed ½ obscured white glass and ½ plain glass ... 4'-0"×7'-0".
S: Window, glazed ... 4'-0"×5'-6".

Sunshades: Construct the sunshades over the windows in operation and dressing rooms for males and females, of plain Mangalore tiles on teak reepers and bracketed frames as shown upon the drawings. Roofs: With the exception of the roofs over skylights over passages, cover the roof with Madras Terrace consisting of brick on edge, 3" concrete, 3 courses of flat tiles, top and bottom, lime plastered. Construct the roof over skylights with glazed Mangalore tiles except those portions resting on walls all round which will be of earthen Mangalore tiles. Provide and fix ½" teak or other ceiling boarding under the rafters over the lantern of dispensary room. Flooring: Pave the floors with any suitable class of patent stone on 4" concrete. Where the soil is damp the filling below the flooring should be river sand, gravel or brick rubble. Finishing: The interior walls of clinical laboratory, dressing, operation and examination rooms will be painted with paripan or other suitable white glossy washable paint on a coat of Portland cement, ½" thick. The interior walls of the other rooms and the exterior ones throughout will be plastered with two coats of lime mortar. Where good stone is available, the exterior should be flush pointed with lime mortar. Paint the roof timbers with two coats of approved paint; girders, doors and windows with three coats of approved colour. Where woodwork is exposed to weather, lead paint shall be used instead of zinc paint. Cost: The building shown upon the drawings is estimated to cost from Rs. 18,200 to Rs. 27,300 according to locality.

Abstract Of Quantities For An Out-Patient Dispensary: Plates 67, 68, 69 And 70.

Quantity.	Description of work.
11,216 c. ft. ...	Excavation for foundations.
7,568 „ ...	Filling in basement.
5,816 „ ...	Concrete, broken brick in lime mortar.
6,244 „ ...	Brick in lime mortar, foundations and basement.
10,819 „ ...	Do., superstructure.
673 „ ...	Archwork, brick in lime mortar.
369 r. ft. ...	Brick cornice, projecting 9", brick in lime mortar.
61 c. ft. ...	Cutstone work.
6·02 tons ...	Rolled steel joists.
6·02 „ ...	Hoisting and setting the joists.
Lump sum ...	Holding down bolts and nuts with gusset plates to connect girders of lantern.
„	Sheet iron ventilating pipe for dark room including black painting, wind ties, cap complete as per drawing.
„	Zinc downfall pipes, 4" diameter.
572·68 c. ft. ...	Timber, wrought and put up.
45 r. ft. ...	Wooden moulding including fixing and painting, complete.
34 sq. ft. ...	Wooden eave boards, 1" thick including fixing, painting, complete.
111 „ ...	Ceiling plank, ½" thick, including fixing, painting, complete.
574 „ ...	Doors, panelled (not raised panels) with frames and iron fittings, complete.
Nos. 4 ...	Ticket windows with sliding shutters including frames, counter boards with supports, iron fittings, complete.
193 sq. ft. ...	United steel sash window including glazing with 21 oz. glass and opening gear, complete.
224 „ ...	Windows, glazed, half obscured white glass and half plain glass including frames and iron fittings, complete.

Quantity.	Description of work.
132 sq. ft. ...	Windows, glazed with frames and iron fittings, complete.
127 „ ...	Skylight with frames, fixed glazed shutters and perforated zinc sheet between them.
5,310 „ ...	Terrace roofing with brick on edge, 3" concrete, three courses of flat tiles, top and bottom, lime plastered.
89 „ ...	Roofing with glazed Mangalore tiles including reepers.
87 „ ...	Roofing with plain Mangalore tiles including reepers.
264 „ ...	Plain Mangalore tiled sunshades supported on wooden brackets including reepers, painting, complete.
5,059 „ ...	Levelling course of concrete, 4" thick.
5,472 „ ...	Paving with patent stone.
539 „ ...	Paving with thin Cuddapah slabs over ½" lime mortar and pointing with Portland cement.
5,711 „ ...	Plastering with cement, ½" thick and painting with paripan.
13,794 „ ...	Plastering with lime mortar, two coats, interior and exterior.
3,449 „ ...	Painting, three coats.
5,507 „ ...	Painting, two coats.
204 „ ...	2½" Ferro concrete partition including fixing, finishing, complete.
38 r. ft. ...	Reinforced concrete lintel, 6" deep and 1' 1½" wide.
	Contingencies at 5 per cent.
	Petty supervision at 2½ per cent.
	Total Rs. ...

An Out-Patient Dispensary: Plates 71 And 72.

In the above plates is illustrated the type design No. 162 issued with proceedings of the Madras Sanitary Board, No. 1055-S., dated 18-11-1914. The specification report which accompanied this design was as follows: Foundations: A depth of 3 feet is provided, the lower 1′ 6″ being concrete of broken brick in lime mortar and the upper 1′6″, brick in lime mortar. Basement: Brick in lime mortar, 1′6″ high. Pressure: Maximum pressure on the soil is 0·80 ton per square foot. Walling: All walls will be of brick in lime mortar according to the thickness shown upon the drawing. Stone-work: Bed stones under girders, bases of verandah posts, corbels to support verandah wall purlins, sills of doors (flush with floor) and of iron grated openings will be of cut stone. Woodwork: All woodwork will be of well seasoned wood. Doors and windows: All doors and windows will be of teakwood according to the lettered description given below:

A:	Door, ⅓ panelled and ⅔ glazed...	4′-0″×8′-0″.
B:	Door, panelled	4′-0″×8′-0″.
C:	Window, glazed, pivoted top and bottom	4′-0″×5′-0″.
D:	Window, glazed, pivoted top and bottom	3′-0″×5′-0″.
E:	Door, braced and battened ...	3′-0″×6′-6″.
F:	Door, braced and battened ...	2′-6″×6′-6″.
G:	Window, frosted glass ...	3′-0″×4′-0″.
H:	Ventilators, glazed with wire netting	4′-0″×1′-6″.
K:	Fixed, iron grating ...	4′-3″×10′-0″.
L:	Iron grated door, with counters	4′-7½″×9′-0″.
M:	Single leaf door, ⅓ panelled and ⅔ glazed	4′-6″×8′-6″.
N:	Ventilators, glazed, (semi-circular)	4′-0″×3′-0″.
O:	Window	6′-0″×6′-0″.

Roofing: Roofing over waiting rooms, operation and dark rooms, clinical laboratory, and store room will be of Madras terrace. Roofing over other rooms and verandahs will be of fibro-cement slates on teak reepers. The surgeon's dressing and dispensary rooms in addition have ½″ plank ceiling underneath. Flooring: The flooring of all rooms with the exception of latrines will be of any suitable colour of Indian patent stone on 4″ concrete. The flooring of latrines will be of thin stone slabs on 4″ concrete and pointed with Portland cement. Finishing: The interior of surgeon's, dressing and operation rooms will be painted with paripan or other suitable white glossy washable paint on a coat of Portland cement, ½″ thick. The interior of all other rooms except the latrines will be plastered with two coats of lime mortar. The interior of latrines will be plastered with Portland cement. The exterior throughout will be plastered with lime mortar, two coats. All doors, windows and ventilators and girders will be painted three coats of approved paint and the roof timbers painted two coats. Cost: The cost of the building will vary from Rs. 13,200 to Rs. 19,800 according to locality.

Abstract Of Quantities For An Out-Patient Dispensary: Plates 71 and 72.

Quantity.	Description of work.
7,813 c. ft. ...	Earthwork, excavation for foundations.
5,448 „ ...	Filling in basement with earth.
3,939 „ ...	Concrete, broken brick in lime mortar.
4,803 „ ...	Brick in lime mortar (foundations and basement).
6,837 „ ...	Brick in superstructure.
70 r. ft. ...	Columns, 1′ 3″ diameter, brick in lime mortar with base, capital and bond stones including plastering, complete.
223 c. ft. ...	Archwork, brick in lime mortar.
66 r. ft. ...	Cornice, projection 9″, brick in lime mortar.
191 „ ...	Coping, projection 3″, brick in lime mortar.
103 c. ft. ...	Cutstone work.
1·32 tons. ...	Rolled steel joists.
1·32 „ ...	Hoisting and setting the rolled steel joists.

Quantity.	Description of work.
191·38 lbs. ...	Wrought-iron work.
430·00 c. ft. ...	Timber, wrought and put up.
148 sq. ft. ...	Teak barge board including 2 coats of painting, complete.
158 „ ...	Teak partition with necessary frames and doors including painting, complete.
262 „ ...	Doors, $\frac{1}{3}$ panelled and $\frac{2}{3}$ glazed with frames and iron fittings, complete.
128 „ ...	Doors, panelled with frames and iron fittings, complete.
81 „ ...	Fixed iron grating with necessary fittings, complete.
83 „ ...	Iron grating door with counters.
72 „ ...	Doors, braced and battened with frames and fittings, complete.
140 „ ...	Windows, glazed, pivoted top and bottom including frames and fittings, complete.
24 „ ...	Windows, frosted glass with frames and fittings, complete.
72 „ ...	Windows, glazed, iron casement.
12 „ ...	Ventilators with fixed glazed shutters and perforated zinc sheet between them.
20 „ ...	Ventilators, glazed with frames and fittings, complete.
877 „ ...	Terrace roofing with brick on edge, 5" concrete, 3 courses of flat tiles, top and bottom, lime plastered.
4,584 „ ...	Roofing with fibro-cement slates including teak reepers, complete.
780 „ ...	Wooden ceiling ($\frac{1}{2}$" plank) including two coats of painting.
3,347 „ ...	Levelling course of concrete, 4" thick.
4,101 „ ...	Paving with patent stones.
4,968 „ ..	Plastering with cement, $\frac{1}{2}$" thick, and painting with paripan, two coats.
604 „ ...	Plastering with Portland cement, $\frac{1}{2}$" thick.
6,958 „ ...	Plastering with lime mortar, two coats.
1,862 „ ...	Painting, three coats.
4,984 „ ...	Painting, two coats.
No. 3. ...	Counters with necessary frames and fittings, complete.
207 sq. ft. ...	Zinc sheet for valleys.
	Contingencies at 5 per cent.
	Petty supervision at $2\frac{1}{2}$ per cent.
	Total Rs.

An Out-Patient Dispensary With An Operation Room: Plates 73 And 74.

In the above plates is illustrated the type design No. 163 issued with proceedings of the Madras Sanitary Board, No. 1056-S., dated 18-11-1914. The specification report which accompanied this design was as follows: Foundations: A depth of 3' will be provided, the lower 1' 6" being stone concrete in lime mortar, the upper 1' 6" being rough stone in lime mortar. 2. Basement: Basement will be 2' high of rough stone in lime mortar. 3. Walling: All walls will be of rough stone in lime mortar according to the thickness shown on the drawing. The lintels will be of ferro-concrete slab. 4. Woodwork: All woodwork will be of well-seasoned teakwood. 5. Doors, windows and ventilators: All doors and windows will be of well-seasoned teakwood and will be of the description given below:

A:	Doors, $\frac{1}{3}$ panelled and $\frac{2}{3}$ glazed	4'-0" × 8'-0".
B:	Doors, panelled ...	4'-0" × 8'-0".
C:	Windows, glazed with iron bars	4'-0" × 5'-0".
D:	Windows, glazed ...	4'-0" × 5'-0".
E:	Windows, glazed with mullions	6'-0" × 7'-9".
F:	Ticket windows, panelled ...	1'-6" × 1'-10$\frac{1}{2}$".
G:	Doors, $\frac{1}{3}$ panelled and $\frac{2}{3}$ ground glass	4'-0" × 8'-0".
H:	Ventilators, glazed and pivoted	4'-0" × 3'-0".

6. Teakwood sunshades with necessary supports and brackets will be provided over windows of dressing rooms. 7. Roofing: Roofing throughout will be of Madras terracing. 8. Flooring: The operation room will be paved with marble slabs over 4" concrete and pointed with cement. All the other rooms will be floored with rubbed Cuddapah slabs over 4" concrete and pointed with cement. The floor of waiting places will be ordinary Cuddapah slabs. 9. Finishing: The interior of all rooms will be plastered with lime mortar, two coats, except operation room which will be faced with white glazed tiled dado for 5' height from floor and above which plastered with cement, $\frac{1}{2}$ inch thick and painted with paripan. The exterior throughout will be pointed with prepared mortar. 10. Doors and windows will be painted with three coats of approved paint and roof timbers with two coats of approved paint. 11. Cost: The cost of the building as shown upon the drawings will vary from Rs. 5,450 to Rs. 8,175 according to locality.

Abstract Of Quantities For An Out-Patient Dispensary With An Operation Room: Plates 73 And 74.

Quantity.	Description of work.
3,848 c. ft. ...	Earthwork, excavation for foundations.
1,808 „ ...	Filling in basement with earth.
1,954 „ ...	Concrete, stone in lime mortar.
2,546 „ ...	Rough stone in lime mortar in foundations and basement.
4,935 „ ...	Rough stone in lime mortar in superstructure.
161 „ ...	Dressed stone work.
39 „ ...	Archwork, stone in lime mortar.
155 „ ..	Ferro-concrete slab work.
226 sq. ft. ...	Cuddapah slab chajja including supporting cornice, complete.

Quantity.	Description of work.
98·77 c. ft. ...	Timber, wrought and put up.
32 sq. ft. ...	Teak doors, ⅓ panelled and ⅔ glazed with frames and fittings, etc., complete.
128 „ ...	Teak door, panelled with frames and fittings, complete.
128 „ ...	Teak door, ⅓ panelled and ⅔ ground glass with frames and fittings, complete.
40 „ ...	Teak windows, glazed, with iron bars including frames and fittings, etc., complete.
80 „ ...	Teak windows, glazed, with frames and fittings, etc., complete.
47 „ ...	Teak window, glazed with mullions including frames and fittings, complete.
8 „ ...	Teak ticket windows, panelled with frames and fittings, etc., complete.
120 „ ...	Teak ventilators, glazed and pivoted with frames and fittings, complete.
122 „ ...	Teak sunshades with necessary frames, barge boards and brackets including painting, etc., complete.
1,802 „ ...	Terrace roofing with brick on edge, 5" concrete, 3 courses of flat tiles, top and bottom, lime plastered.
1,206 „ ...	Levelling course of stone concrete, 4" thick.
153 „ ...	Paving with white marble slabs over ½" mortar and pointing with Portland cement.
839 „ ...	Paving with rubbed Cuddapah slabs over ½" mortar and pointing with Portland cement.
504 „ ...	Paving with ordinary Cuddapah slabs over ½" mortar and pointing with Portland cement.
5,042 „ ...	Pointing with cement mortar.
463 „ ...	Plastering with ½" Portland cement and painting with paripan.
2,681 „ ...	Plastering with lime mortar, two coats.
248 „ ...	Dado tile work.
894 „ ...	Painting, three coats.
1,045 „ ...	Painting, two coats.
44 r. ft. ...	Cast iron hand rails including painting.
	Contingencies at 5 per cent.
	Petty supervision at 2½ per cent.
	Total Rs. ...

An Out-Patient Dispensary (Small): Plate 75.

In the above plate is illustrated the type design No. 169 issued with proceedings of the Madras Sanitary Board, No. 666-S., dated 4-9-1915. The specification report which accompanied this design was as follows: Foundation: A depth of 3′ 0″ is provided in the estimate, the lower 1′ 6″ of concrete, broken brick in lime mortar and the upper 1′ 6″ of brick in lime mortar. Basement: Basement will be 2′ 0″ deep to be built of brick in lime mortar. Walling: The superstructure will be of brick in lime mortar according to the thickness shown on the drawing. Stonework: Bases of verandah posts, corbels in verandahs and sill stones of doors will be of cutstone. Woodwork: All roof timbers will be of best teak scantlings to be provided according to Chief Engineer's Circular Memorandum No. 234 C., dated 9th January, 1908. Doors and windows: These will be of best Burmah teak according to the lettered description given below:

A:	Doors, ⅓ panelled and ⅔ glazed.	4′-0″ × 8′-0″.
B:	Doors, panelled	4′-0″ × 8′-0″.
C:	Doors, ⅓ panelled and ⅔ glazed.	3′-0″ × 7′-0″.
D:	Doors, panelled	3′-0″ × 7′-0″.
E:	Windows, glazed ...	6′-0″ × 7′-0″.
F:	Windows, glazed ...	3′-0″ × 4′-0″.
G:	Ticket windows, panelled ...	1′-6″ × 1′-10½″.

Roofing: Roof over all rooms will be of Madras terracing. Roofs of side verandahs will be of Mangalore tiles over flat tiles on teak reepers. Flooring: Floors of all rooms and verandahs will be of ½″ cement plaster over 4″ concrete bed. The steps will be paved with Cuddapah slabs. Finishing: The doors and windows will be painted with three coats of approved paint and the roof timbers with two coats. Cost: The building shown on the drawing is estimated to cost from Rs. 3,100 to Rs. 4,650 according to locality.

Abstract Of Quantities For An Out-Patient Dispensary (Small): Plate 75.

Quantity.	Description of work.
2,455 c. ft. ...	Excavation for foundations.
1,105 „ ...	Filling in basement with earth.
1,271 „ ...	Concrete, broken brick in lime mortar.
1,488 „ ...	Brick in lime mortar (foundations and basement).
3,211 „ ...	Brick in lime mortar (superstructure).
94 „ ...	Archwork, brick in lime mortar.
18 „ ...	Cutstone work.
95·00 „ ...	Timber, wrought and put up (teak).
106 sq. ft. ...	Doors, ⅓ panelled and ⅔ glazed with frames and fittings, complete.
116 „ ...	Doors, panelled with frames and fittings, complete.
156 „ ...	Windows, glazed, with frames and fittings, complete.
6 „ ...	Ticket windows, panelled with frames and fittings, complete.
662 „ ...	Terrace roofing with brick on edge, 3″ concrete, three courses of flat tiles, top and bottom, lime plastered.
240 „ ...	Roofing with Mangalore tiles imbedded in mortar over flat tiles including teak reepers, complete.
736 „ ...	Levelling course of concrete, 4″ thick.
861 „ ...	Rendering with Portland cement, ½″ thick.
104 „ ...	Paving with Cuddapah slabs over ½″ lime mortar and pointing with cement.
6,288 „ ...	Plastering with lime mortar, 2 coats.
616 „ ...	Painting, 3 coats.
1,086 „ ...	Painting, 2 coats.

Quantity.	Description of work.
No. 2.	... Wooden seats in verandahs.
No. 2.	... Wooden screens 3' 6" long and 7' high in consulting room.
	Contingencies at 5' per cent.
	Petty supervision at 2½ per cent.
	Total Rs.

General Store Rooms: Plate 76.

In the above plate is illustrated the type design No. 126 issued with proceedings of the Madras Sanitary Board, No. 686-S., dated 10-12-1912. The specification report which accompanied this design was as follows: Foundations: A depth of 3 feet is provided, the lower 1 foot 6 inches being concrete, broken brick in lime mortar and the upper 1 foot 6 inches, brick in lime mortar. The depth and width of foundations will be settled according to the nature of the soil. Basement: Brick in lime mortar, 2 feet high. Pressure: The maximum pressure on the soil is 0'46 ton per square foot. Walling: Walls and archwork will be of brick in lime mortar. Cutstone work: Base stones of verandah posts. Woodwork: One of the timbers mentioned in Circular No. 2040-C., dated 27th April 1909 as applicable to Table I of Circular No. 234-C. of 9th January 1908 should be used. Doors and windows: Teak as per list given below:

A: Panelled doors ... ... 4'-0"×8'-0".
B: Batten windows with iron bars... 4'-0"×5'-0".
C: Do. do. ... 2' 0"×4'-0".

Roofing: Plain Mangalore tiles over teak reepers. Flooring: To be paved with thin Cuddapah slabs over 4 inches concrete pointed with Portland cement. Finishing: Plastering with two coats of lime plaster, both inside and outside of walls. Doors and windows will be painted three coats of approved paint and the roof timbers, two coats. Cost: The building shown upon the drawing is estimated to cost from Rs. 2,400 to Rs. 3,600 according to locality.

Abstract Of Quantities For General Store Rooms: Plate 76.

Quantity.	Description of work.
2,159 c. ft.	... Excavation for foundations.
1,106 „	... Filling in basement with earth.
1,096 „	... Concrete, broken brick in lime mortar.
1,450 „	... Brick in lime mortar (foundation and basement).
2,234 „	... Brick in lime mortar (superstructure).
103 „	... Archwork, brick in lime mortar.
2 „	... Cutstone work.

Quantity.	Description of work.
79'47 c. ft.	... Timber, wrought and put up.
29 sq. ft.	... Weather boarding, ½" thick.
224 „	... Teak doors, panelled with frames and fittings, complete.
196 „	... Battened windows with iron bars including frames, and iron fittings, complete.
1,584 „	... Roofing with plain Mangalore tiles over teak reepers, complete.
743 „	... Levelling course of concrete, 4" thick.
990 „	... Paving with thin Cuddapah slabs pointed with Portland cement.
5,073 „	... Plastering with 2 coats of lime plaster.
1,043 „	... Painting, 3 coats.
971 „	... Painting, 2 coats.
	Contingencies at 5 per cent.
	Petty supervision at 2½ per cent.
	Total Rs. ...

Kitchen: Plates 77, 78, 79 And 80.

In the above plates are illustrated the type designs Nos. 127 and 128 issued with proceedings of the Madras Sanitary Board, No. 686-S., dated 10-12-1912. The specification report which accompanied these designs was as follows: Foundations: A depth of 3 feet is provided the lower 1 foot 6 inches being concrete broken brick in lime mortar and the upper 1 foot 6 inches, brick in lime mortar. The depth and width of foundations will be settled according to the nature of the soil. Basement: Brick in lime mortar, 2 feet high. Pressure: Pressure on the soil is 0'45 ton per square foot. Walling: Walls and archwork will be built of brick in lime mortar. Woodwork: One of the timbers mentioned in Circular 2040-C., dated 27th April 1909, as applicable to Table I of Circular 234 C., dated 9th January 1908, should be used. Doors and windows: Teakwood as per list given below:

A: Doors, fly proof inside, batten shutter outside ... ... 3'-6"×7'-0".
B: Windows, fly proof outside, glazed shutter inside ... 3'-0"×7'-0".
C: Windows, battened ... 3'-0"×4'-0".

Roofing: Plain Mangalore tiles over teak reepers. Flooring: Will be paved with any suitable class of patent stone over 4" concrete laid with a continuous slope in one direction, towards a channel along the walls. Finishing: Both interior and exterior will be plastered, two coats, and whitewashed. Doors and windows will be painted three coats and the roof timbers two coats of approved paint. Cost: The building shown upon the drawings is estimated to cost from Rs. 1,170 to Rs. 1,760 according to locality.

Abstract Of Quantities For A Kitchen: Plates 77, 78, 79 And 80.

Quantity.	Description of work.
1,036 c. ft. ...	Excavation for foundations.
432 „ ...	Filling in basement with earth.
529 „ ...	Concrete, broken brick in lime mortar.
735 „ ...	Brick in lime mortar (foundation and basement).
1,296 „ ...	Brick in lime mortar (superstructure).
66 „ ...	Archwork, brick in lime mortar.
36·59 „ ...	Timber, wrought and put up.
49 sq. ft. ...	Doors, inside swing fly proof gauze shutter, and outside panelled shutter (single leaf) to fold back against the wall.
56 „ ...	Windows, outside swing fly proof, inside glazed shutters complete.
48 „ ...	Windows, battened with frames and iron fittings complete.
662 „ ...	Roofing with plain Mangalore tiles over teak reepers complete.
256 „ ...	Levelling course of concrete, 4" thick.
317 „ ...	Paving with patent stone.
2,471 „ ...	Plastering with lime mortar, two coats and white-washing.
472 „ ...	Painting, three coats.
499 „ ...	Painting, two coats.
	Finishing the chimney with plastering, two coats and white-washing complete.
	Constructing cooking range with counter, pot oven, etc., complete.
	Providing tubs and pipes, etc., for kitchen.
	Contingencies at 5 per cent.
	Petty supervision at 2½ per cent.
	Total Rs. ...

Quarters For Hospital Servants (6 Compartments): Plates 81 And 82.

In the above plates is illustrated the type design No. 131 issued with proceedings of the Madras Sanitary Board, No. 686-S., dated 10-12-1912. The specification report which accompanied this design was as follows: Foundations: A depth of 3 feet is provided, the lower 1 foot 6 inches being concrete of broken brick in lime mortar and the upper 1 foot 6 inches of brick in lime mortar. Basement: Brick in lime mortar, 2 feet high. Pressure: Maximum pressure on the soil is 0·47 ton per square foot. Walling: Walls and archwork will be built of brick in lime mortar. Cutstone work: Base stones of verandah posts. Woodwork: One of the timbers mentioned in Circular No. 2040 C., dated 27th April 1909 as applicable to Table I in Circular No. 234-C., dated 9th January 1908, should be used. Doors and windows: Teak as per list given below:

A: Door, battened ... ... 3'-0"×6'-6".
B: Door, battened ... ... 2'-6"×6'-6".
C: Window, battened with iron bars 3'-0"×4'-0".

Roofing: With the exception of the roof over cooking shed, cover the roof with Mangalore tiles over flat tiles with air spaces. The roof over cooking shed will be of plain Mangalore tiles on teak reepers. Flooring: Will be paved with thin stone slabs pointed with Portland cement or rendered with ½" Portland cement over 4 inches concrete. Finishing: The interior and exterior will be plastered with two coats of lime mortar. Doors and windows will be painted with 3 coats of approved colour and roof timbers with 2 coats of approved paint. Cost: The building shown upon the drawings is estimated to cost from Rs. 4,700 to Rs. 7,100 according to locality.

Abstract Of Quantities For Quarters For Hospital Servants (6 Compartments): Plates 81 And 82.

Quantity.	Description of work.
4,948 c. ft. ...	Excavation for foundations.
3,103 „ ...	Filling in basement with earth.
2,514 „ ...	Concrete, broken brick in lime mortar.
3,278 „ ...	Brick in lime mortar (foundations).
4,041 „ ...	Do. (superstructure).
131 „ ...	Archwork, brick in lime mortar.
3 c. ft. ...	Cutstone work.
200·71 „ ...	Timber, wrought and put up.
332 sq. ft. ...	Doors, batten, with frames and iron fittings complete.
144 „ ...	Windows, batten, with iron bars including frames and iron fittings.
2,450 „ ...	Roofing with Mangalore tiles over flat tiles with air spaces including teak reepers.
1,104 „ ...	Roofing with plain Mangalore tiles on teak reepers.
2,010 „ ...	Levelling course of concrete, 4" thick.
2,427 „ ...	Paving with thin stone slabs pointed with Portland cement.
9,406 „ ...	Plastering with two coats of lime mortar, inside and outside.
1,142 „ ...	Painting, three coats.
2,464 „ ...	Painting, two coats.
	Contingencies at 5 per cent.
	Petty supervision at 2½ per cent.
	Total Rs. ...

Sub Assistant-Surgeon's Quarters: Plates 83 And 84.

In the above plates is illustrated the type design No. 141 issued with proceedings of the Madras Sanitary Board, No. 41-S, dated 16-1-1913. The specification report which accompanied this design was as follows: Foundations: A depth of 3' 6" is provided in the quantities, the lower 1' 6" being concrete of broken brick in lime mortar and the upper 2' 0", country brick in lime mortar. The required depth and width of foundations will be settled according to the nature of the soil.

Basement will consist of brick in lime mortar 1′ 6″ high for main building and 1′ 0″ high for out-houses and compound wall. In localities where the nature of lime obtainable is such as to render the use of surkhi desirable, surkhi may be used. Walling will be of brick in clay except (1) 1 foot round doors, windows and cupboards, (2) 1 foot at top of walls, (3) archwork, (4) pillars in bath rooms to receive the ridge pieces, (5) top of chimney, (6) pillars and coping of compound wall and (7) thin wall for sink and seats of latrine, which will be of brick in lime mortar. Stonework: Dressed base stones 9″×9″×5″ are provided under verandah posts. Provide also lintel to carry chimney wall above roof. Woodwork: One of the timbers mentioned in Circular No. 2040-C., dated 27th April 1909, as applicable to Table I of Circular No. 234-C., dated 9th January 1908, should be used. Doors and windows are to be of the description given below:

A: Door, panelled	...	3′-0″×7′-0″.
B: Door, panelled	...	2′-6″×6′-6″.
C: Door, panelled	...	3′-0″×6′-6″.
D: Door, braced and battened	...	3′-0″×5′-0″.
E: Window, venetianed with iron bars ...	...	3′-0″×4′-0″.
F: Window, battened	...	2′-0″×4′-0″.
G: Window, battened with iron bars ...	...	3′-0″×4′-0″.

Sunshades: Construct the sunshade over the windows in bed and dining rooms of plain Mangalore tiles on teak reepers and teak brackets. Roofs: With the exception of the roofs over bath rooms and kitchen, cover the roofs with Mangalore tiles bedded in lime mortar over flat tiles as per Memorandum No. 4235-C., dated 24th August, 1907. Construct the roof over bath room and kitchen of plain Mangalore tiles on teak reepers. Flooring: Construct the floors of dining, bed, store and bath rooms, kitchen, latrine and verandahs with 4″ of concrete rendered with Portland cement ½″ thick. Spread 3″ of gravel in the floor of open yard, water and ram well. Finishing: Cover the interior and exterior of walls with two coats of lime plaster except the interior walls of latrine which will be rendered with ½″ Portland cement to a height of 3 feet. Doors, windows and exposed timber will be painted two coats of approved colour and the interior woodwork wood oiled, two coats. Construct two tiers of teak or other wooden shelves 3′-0″×4′-0″ with necessary fittings and shutters, one in kitchen and the other in bed room. Fit the walls of store room with a row of 1″ thick Cuddapah slab shelves projecting 1′-6″ from the wall supported by wooden brackets. Cost: The building shown upon the drawings is estimated to cost from Rs. 2,100 to Rs. 3,100 according to locality.

Abstract Of Quantities For Sub-Assistant Surgeon's Quarters: Plates 83 And 84.

Quantity.	Description of work.
2,721 c. ft.	... Excavation for foundations.
601 „	... Filling in basement with earth.
1,226 „	... Concrete, broken brick in lime mortar.
1,397 „	... Country brick in lime mortar (foundations and basement).
1,412 „	... Country brick in clay (superstructure).
641 „	... Country brick in lime mortar (superstructure).
101 „	... Archwork, brick in lime mortar.
7 „	... Cutstone work.
89·92 „	... Timber, wrought and put up.
965 sq. ft.	... Roofing with Mangalore tiles imbedded in mortar over flat tiles including teak reepers, complete.
341 „	... Roofing with plain Mangalore tiles including teak reepers, complete.
43 „	... Plain Mangalore tiled sunshades with necessary brackets and painting, complete.
201 c. ft.	... Levelling course of concrete, 4″ thick.
752 sq. ft.	... Rendering with ½″ Portland cement.
237 „	... Flooring with gravel, 3″ thick, well watered and rammed.
153 „	... Doors, panelled, including frames and iron fastenings, complete.
15 „	... Doors, braced and battened, including frames and iron fastenings, complete.
48 „	... Windows, venetianed with iron bars, including frames and iron fastenings, complete.
16 „	... Windows, battened, including frames and iron fittings, complete.
12 „	... Windows, battened with iron bars, including frames and iron fastenings, complete.
4,335 „	... Plastering with lime mortar, two coats.
144 „	... Plastering with cement, ½″ thick.
944 „	... Painting, two coats.
948 „	... Wood-oiling, two coats.
24 „	... Cup-board with necessary fittings, complete.
9 „	... Cuddapah slab shelves.
Lump sum	... Finishing the chimney.
„	... Ovens.
4 lbs.	... Wrought-iron work.
	Contingencies at 5 per cent.
	Petty supervision at 2½ per cent.
	Total Rs...

Quarters For A Civil Apothecary Or Assistant Surgeon: Plate 85.

In the above plate is illustrated the type design No. 146 issued with proceedings of the Madras Sanitary Board No. 490-S, dated 6-8-1913. The specification report which accompanied this design was as follows: Foundations: A depth of 3 feet is provided, the lower 1 foot 6 inches being concrete of broken brick in lime mortar and the upper 1 foot 6 inches, country brick in lime mortar. The actual depth and nature of foundations will be settled

locally to suit the soil. Basement will be country brick in lime mortar, 1 foot 6 inches high. Walling: Walls will be country brick in clay except (1) arch-work, (2) 1 foot on top of walls and round doors and windows, which will be built of country brick in lime mortar. Cutstone work: Base stones are provided under verandah posts. Woodwork: The scantlings provided are suited to any one of the timbers mentioned in Circular No. 2040-C., dated 27th April 1909, as applicable to Table I of Circular No. 234-C., dated 9th January 1908. Doors and windows will be of teak as per description given below:

A:	Doors, $\frac{1}{3}$ panelled and $\frac{2}{3}$ glazed.	3'-6"×7'-6".
B:	Doors, panelled	3'-6"×7'-6".
C:	Doors, panelled	2'-6"×6'-6".
D:	Windows, glazed	3'-6"×4'-6".
E:	Windows, venetianed ...	3'-6"×4'-6".
F:	Windows, venetianed ...	3'-0"×4'-0".

Roofing throughout will be of Mangalore tiles imbedded in mortar over flat tiles. Sunshades will be of plain Mangalore tiles on teak rafters and bracketed frames as shown on the drawing. Flooring: With the exception of bath rooms, pantry, store and verandah, the flooring will consist of square tiles over 4 inches concrete, pointed with Portland cement. The floors of bath, pantry, store and verandah will be rendered with $\frac{1}{2}$ inch Portland cement over 4 inches concrete. Pave the steps with stone slabs over $\frac{1}{2}$ inch lime mortar, pointed with Portland cement. Finishing: The interior and exterior of walls throughout will be plastered with 2 coats of lime mortar. Doors, windows and verandah posts and bressummers will be painted 3 coats of approved paint and all roof timbers, 2 coats of approved colour. Construct in the pantry 2 tiers of teak or other wooden shelves, 3 shelves in each tier, each shelf measuring $1\frac{1}{4}$ inch thick, 12 inches from front to back and 3 feet in width, the vertical distance between the shelves being about 14 inches. Enclose one of the tiers of the shelves with $1\frac{1}{4}$ inch square framed doors hung folding with 3 inches iron butts and fitted with hasp and staple to receive a padlock. Fit the walls of store room with 3 rows of 1 inch thick Cuddapah slab shelves built into the wall and projecting 1 foot 6 inches. Out-houses: The foundations for cook house will be 3 feet deep, of which the bottom 1 foot is broken brick in lime mortar, the rest, country brick in lime mortar. The foundations for the latrine will be 2 feet 6 inches deep, of which the bottom 1 foot 6 inches is broken brick in lime mortar, and the rest, country brick in lime mortar. The actual depth and nature of foundations will be settled locally to suit the soil. Basement will consist of country brick in lime mortar, 1 foot 6 inches and 6 inches high, respectively for the cook house and latrine. Walling: The walls of latrine will be of country brick in lime mortar and those of cook house country brick in clay, except 1 foot at top of walls and around doors and windows, arches and top of chimney, which will be of country brick in lime mortar. Woodwork: The scantlings provided are suited to any of the timbers mentioned in Circular No. 2040-C., dated 27th April 1909, as applicable to Table I of Circular No. 234-C., dated 9th January 1908. Doors and windows will be of teak. Roofing will be of plain Mangalore tiles on teak reepers. Flooring will be of square tiles over 4 inches concrete pointed with Portland cement for cook house, and $\frac{1}{2}$ inch Portland cement over 4 inches concrete for latrine. Finishing: The internal and external walls throughout will be plastered with 2 coats of lime mortar except the internal walls of latrine which will be rendered with $\frac{1}{2}$ inch Portland cement to a height of 3 feet. Doors, windows and all roof timbers will be painted two coats of approved paint. Cost: The building shown upon the drawing is estimated to cost from Rs. 4,000 to Rs. 6,000 according to locality.

Abstract Of Quantities For Quarters For A Civil Apothecary Or Assistant Surgeon: Plate 85.

Quantity.		Description of work.
2,932 c. ft.	...	Excavation for foundations.
1,260 "	...	Filling in basement with earth.
1,494 "	...	Concrete, broken brick in lime mortar.
1,777 "	...	Country brick in lime mortar (foundations and basement).
2,604 "	...	Country brick in clay (superstructure).
179 "	...	Archwork, brick in lime mortar.
947 "	...	Country brick in lime mortar (superstructure).
2 "	...	Cutstone work.
180·77 "	...	Timber, wrought and put up.
79 sq. ft.	...	Doors, $\frac{1}{3}$ panelled and $\frac{2}{3}$ glazed with frames and iron fastenings, complete.
183 "	...	Doors, panelled including frames and iron fastenings, complete.
16 "	...	Windows, glazed including frames and iron fastenings, complete.
119 "	...	Windows, venetianed including frames and iron fastenings, complete.
2,245 "	...	Roofing with Mangalore tiles imbedded in mortar over flat tiles including teak reepers, complete.
97 "	...	Plain Mangalore tiled sun-shades with necessary brackets including painting, complete.
718 "	...	Paving with square tiles over $\frac{1}{2}$" lime mortar and pointing with Portland cement.
598 "	...	Rendering with $\frac{1}{2}$" Portland cement.
73 "	...	Paving with stone slabs over $\frac{1}{2}$" lime mortar and pointing with Portland cement.
1,121 "	...	Levelling course of concrete, 4" thick.

Quantity.	Description of work.
5,487 sq. ft. ...	Plastering with lime mortar, two coats.
1,141 „ ...	Painting, three coats.
2,112 „ ...	Painting, two coats.
30 „ ...	Cup-board with frames, panelled shutters and painting, complete.
6 lbs. ...	Wrought-iron work.
37 sq. ft. ...	Cuddapah slab shelves supported on wooden brackets.
47 „ ...	Zinc sheet for valleys.
	Contingencies at 5 per cent.
	Petty supervision at $2\frac{1}{2}$ per cent.
	Total Rs...
	Cook house.
411 c. ft. ...	Excavation for foundations.
75 „ ...	Filling in basement with earth.
139 „ ...	Concrete, broken brick in lime mortar.
241 „ ...	Country brick in lime mortar (foundations and basement).
326 „ ...	Country brick in clay (superstructure).
173 „ ...	Country brick in lime mortar (superstructure).
21 „ ...	Archwork, brick in lime mortar.
30 r. ft. ...	Brick cornice work including plastering.
3·72 c. ft. ...	Timber, wrought and put up.
18 sq. ft. ...	Teak batten door with frames and fittings, complete.
11 „ ...	Teak batten window with frame and fittings, complete.
81 „ ...	Roofing with plain Mangalore tiles including teak reepers, complete.
48 „ ...	Flooring with square tiles over 4" sand and pointing with Portland cement.
1,108 „ ...	Plastering with lime mortar, two coats.
103 „ ...	Painting, two coats.
18 „ ...	Cuddapah slabs set in mortar and pointed with Portland cement.
9 „ ...	Teak cup-boards with shutters, fittings and painting, complete.
Lump sum.	Pot oven set in clay.
	Contingencies at 5 per cent.
	Petty supervision at $2\frac{1}{2}$ per cent.
	Total Rs...

Bath Room : Plate 86.

In the above plate is illustrated the type design No. 125 issued with proceedings of the Madras Sanitary Board, No. 686-S., dated 10—12—1912. The specification report which accompanied this design was as follows: Foundations: A depth of 3 feet is provided, the lower 1′ 6″ being concrete, broken brick in lime mortar and the upper 1′ 6″ being brick in lime mortar. The depth and width of foundations will be settled according to the nature of the soil. Pressure : The maximum pressure on the soil in foundations as drawn is 0·41 ton per square foot. Basement: Brick in lime mortar, 2 feet high. Walling: Walls and archwork of brick in lime mortar. Internal corners should be rounded. Cutstone work: Base stones under posts in passage and blocks for door frames. Woodwork: One of the timbers mentioned in Circular No. 2040-C., dated 27th April 1909, as applicable to Table I of Circular No. 234-C., of 9th January 1908 should be used. Doors and windows: Teak as per list given below:

A: Door, battened and braced ... 3′-0″ × 6′-6″.
B: Door, battened and braced ... 2′-6″ × 6′-6″.
C: Window, glazed ... 3′-0″ × 4′-0″.

Roofing: Plain Mangalore tiles on teak reepers over bath rooms and fibro-cement slates on teak reepers over passage: Flooring: Cuddapah slabs over 4 inches of concrete and pointing with Portland cement; or alternatively $\frac{1}{2}$ inch Portland cement over 4 inch concrete. Finishing: Interior of rooms will be plastered with Portland cement and the exterior with lime plaster. Doors and windows will be painted three coats of approved paint and the roof timbers, two coats. Cost: The building shown upon the drawing is estimated to cost from Rs. 660 to Rs. 990 according to locality.

Abstract Of Quantities For A Bath Room: Plate 86.

Quantity.	Description of work.
534 c. ft. ...	Excavation for foundations.
172 „ ...	Filling in basement with earth.
272 „ ...	Concrete, broken brick in lime mortar.
348 „ ..	Brick in lime mortar (foundation and basement).
479 „ ...	Brick in lime mortar (superstructure).
27 „ ...	Archwork, brick in lime mortar.
4 c.ft. ...	Cutstone work.
18·51 „ ...	Timber, wrought and put up.
72 sq. ft. ...	Doors, battened and braced.
24 „ ...	Windows, glazed.
328 „ ...	Roofing with plain Mangalore tiles.
18 „ ...	Roofing with fibro-cement slates.
116 „ ..	Levelling course of concrete, 4" thick.
154 „ ...	Rendering with Portland cement, $\frac{1}{2}$" thick.
609 „ ...	Plastering with cement.
542 „ ...	Plastering with lime mortar, two coats.
185 „ ...	Painting, three coats.
259 „ ...	Painting, two coats.
20 r. ft. ...	Drains.
2 Nos.	Buckets for receiving the sullage water.
	Contingencies at 5 per cent.
	Petty supervision at $2\frac{1}{2}$ per cent.
	Total Rs...
	Constructing a covered passage to the bath room.
150 c. ft. ...	Excavation for foundations.
86 „ ...	Filling in basement with earth.
75 „ ...	Concrete, broken brick in lime mortar.
90 „ ...	Brick in lime mortar (foundation and basement).
1 „ ...	Cutstone work.
11·51 „ ...	Timber, wrought and put up.
120 sq. ft. ...	Roofing with fibro-cement slates.
58 „ ...	Levelling course of concrete, 4" thick.
80 „ ...	Rendering with Portland cement, $\frac{1}{2}$" thick.
40 „ ...	Plastering with lime mortar, two coats.

Quantity.	Description of work.
147 sq. ft. ...	Painting, two coats. Contingencies at 5 per cent. Petty supervision at $2\frac{1}{2}$ per cent. Total for covered passage. Total for bath room. Total for bath room including covered passage.

A Mortuary: Plate 87.

In the above plate is illustrated the type design No. 132 issued with proceedings of the Madras Sanitary Board, No. 686-S., dated 10-12-1912. The specification report which accompanied this design was as follows: Foundations: A depth of 3 feet is provided, the lower 1′ 6″ being concrete broken brick in lime mortar and the upper 1′ 6″, brick in lime mortar. The depth and width of foundations will be settled according to the nature of the soil. Basement: Brick in lime mortar, 1′ 6″ high. Pressure: Pressure on the soil is ·47 ton per square foot. Walling: Walls and archwork will be of brick in lime mortar. Internal corners should be rounded. Stonework: The sills of doors will be provided with cutstone, flush with the floor. Woodwork: One of the timbers mentioned in Circular No. 2040-C., dated 27th April 1909, as applicable to Table I of Circular No. 234-C., dated 9th January 1908, should be used. Doors and windows: Teakwood as per list given below:

A: Door, $\frac{1}{3}$ panelled and $\frac{2}{3}$ venetianed 4′-6″ × 8′-6″.
B: Door, panelled ... 4′-6″ × 8′-6″.
C: Window, glazed ... 7′-0″ × 7′-0″.
D: Window, glazed ... 4′-0″ × 7′-0″.
E: Window, glazed ... 5′-0″ × 7′-0″.
F: Gate ... 10′-0″ × 7′-0″.

The opening at the gable end of the mortuary will be protected by the expanded metal ventilator. The windows C in the post-mortem room must face north. Roofing: Will be covered with Mangalore tiles on flat tiles with air spaces. Flooring: The mortuary, post-mortem and inquest room will be paved with any suitable kind of patent stone on 4 inches concrete. The open yard will be covered with 6 inches gravel. Finishing: Internal walls will be painted with paripan or other suitable glossy white washable paint on a coat of $\frac{1}{2}$ inch Portland cement. External walls will be plastered, two coats, of lime mortar and colour washed. Doors and windows will be painted, three coats, of approved colour and the roof timbers, two coats. Cost: The building shown upon the drawing is estimated to cost from Rs. 2,130 to Rs. 3,200 according to locality.

Abstract Of Quantities For A Mortuary: Plate 87.

Quantity.	Description of work.
1,459 c. ft. ...	Excavation for foundations.
317 „ ...	Filling in basement with earth.
762 „ ...	Concrete, broken brick in lime mortar.
763 „ ...	Brick in lime mortar (foundation and basement)
1,465 „ ...	Do. (superstructure)
70 „ ...	Archwork, brick in lime mortar.
23 „ ...	Cutstone work.
0·09 ton. ...	Rolled steel joists.
43·40 c. ft. ...	Timber, wrought and put up.
153 sq. ft. ...	Doors, $\frac{1}{3}$ panelled and $\frac{2}{3}$ venetianed including frames and fittings, complete.
77 „ ...	Doors, panelled including frames and iron fittings, complete.
196 „ ...	Windows, glazed, including frames and iron fittings, complete.
747 „ ...	Roofing with Mangalore tiles on flat tiles with air spaces.
317 „ ...	Levelling, course of concrete, 4″ thick.
378 „ ...	Paving with Indian patent stone.
463 „ ...	Gravelling, 6″ thick.
1,746 „ ...	Plastering with Portland cement, $\frac{1}{2}$″ thick, and painting with three coats of paripan.
1,865 „ ...	Plastering with two coats of lime mortar and colour washing.
933 „ ...	Painting, three coats.
577 „ ...	Do, two „
No. 2. ...	Zinc buckets.
4 r. ft. ...	Iron pipe, 3″ diameter.
60 sq. ft. ...	Wrought iron gate with fittings and painting, complete.
68 „ ...	Expanded metal ventilator with frames and fittings at gable ends.
	Contingencies at 5 per cent.
	Petty supervision at $2\frac{1}{2}$ per cent.
	Total Rs...

Vaccine Station: Plate 88.

In the above plate is illustrated the type design No. 157 issued with proceedings of the Madras Sanitary Board, No. 539-S., dated 12-6-1914. The specification report which accompanied this design was as follows: Foundations: A depth of 2′ 3″ is provided in the estimate, the lower 1′ 6″ being concrete of broken brick in lime mortar, the footings being 9″ deep of brick in lime mortar. The required depth and width will be settled locally according to the nature of the soil. Basement: Brick in lime mortar, 1′ 6″ high. Superstructure: All walls will be of brick in lime mortar according to the thickness shown upon the drawing. Woodwork: All woodwork will be of well seasoned country wood. Doors and windows: All doors and windows will be of best teakwood. Roofing: Roofing will be of Mangalore tiles bedded in lime mortar over flat tiles. Flooring: The flooring of vaccination room and waiting place will be rendered with Portland

cement, ½" thick, over 4" levelling course of concrete. Finishing: The interior and exterior of vaccination room and waiting place will be plastered with lime mortar, two coats. All doors and windows and roof timbers will be painted with two coats of zinc white paint. Cost: The building shown upon the drawing is estimated to cost from Rs. 750 to Rs. 1,125 according to locality.

Abstract Of Quantities For A Vaccine Station: Plate 88.

Quantity.	Description of work.
431 c. ft. ...	Earthwork excavation for foundations.
185 „ ...	Filling in basement with earth.
290 „ ...	Concrete, broken brick in lime mortar.
312 „ ...	Country brick in lime mortar (foundations and basement).
620 „ ...	Do. superstructure.
13 „ ...	Archwork, brick in lime mortar.
46·78 „ ...	Timber, wrought and put up (country wood).
671 sq. ft. ...	Roofing with Mangalore tiles over flat tiles including teak reepers, etc., complete.
61 c. ft. ..	Levelling course of concrete.
219 sq. ft. ...	Rendering with ½" cement plaster.
19 „ ...	Paving with Cuddapah slabs over ½" mortar and pointed with Portland cement.
1,371 „ ...	Plastering with lime mortar, two coats.
25 „ ...	Teak door, panelled with frames, hinges and other fittings, complete.
45 „ ...	Teak windows, batten outside and glazed inside with frames, hinges and other fittings, complete.
816 „ ...	Painting, two coats, with zinc white paint.
	Contingencies.
	Petty supervision.
	Total Rs...

Isolation Ward: Plates 89 And 90.

In the above plates is illustrated the type design No. 122 issued with proceedings of the Madras Sanitary Board, No. 686-S., dated 10-12-1912. The specification report which accompanied this design was as follows: Foundations: A depth of 3 feet is provided, the lower 1 foot 6 inches being concrete of broken brick in lime mortar and the upper 1 foot 6 inches, brick in lime mortar. Basement: Brick in lime mortar, 2 feet high. Walling: Walls will be constructed with 22 B. W. G. corrugated iron sheets with all necessary horizontal and vertical frames secured properly at base with 1" holding down bolts. Cutstone work: Base stones of verandah posts. Woodwork: One of the timbers mentioned in Circular No. 2040-C of 27th April 1909, as applicable to Table I of Circular No. 234-C. of 9th January 1908, should be used. Doors and windows: Teak as per list given below:

A: Door, ⅓ panelled and ⅔ glazed ... 4'-6"×8'-0".
B: Door, batten ... ... 3'-0"×6'-6".
C: Door, batten ... ... 2'-6"×6'-6".
D: Window, glazed ... ... 4'-6"×5' 0".
E: Window, glazed ... ... 3'-0"×4'-0".
F: Window, glazed ... ... 2'-0"×4'-0".

Roofing will be of Mangalore tiles over flat tiles with air spaces on teak reepers. Flooring: Ward rooms, latrines, bath rooms, verandahs and passages will be paved with thin Cuddapah slabs on 4 inches concrete bed and pointed with Portland cement or rendered with ½" Portland cement over 4 inches concrete. Finishing: The interior of all rooms and latrine will be painted with two coats of zinc white, and the exterior two coats of grey. All doors and windows will be painted with three coats of approved colour and the roof timbers with two coats of approved paint. The exterior of basement all round will be plastered with lime mortar, two coats. Cost: The building shown on the drawings is estimated to cost from Rs. 10,630 to Rs. 15,900 according to locality.

Abstract Of Quantities For An Isolation Ward: Plates 89 And 90.

Quantity.	Description of work.
5,885 c. ft. ...	Earthwork excavation for foundations.
5,750 „ ...	Filling in basement with earth.
2,970 „ ...	Concrete, broken brick in lime mortar.
3,650 „ ...	Brick in mortar in foundation and basement.
11 „ ...	Cutstone work.
523 lbs. ...	Wrought-iron work.
818·38 c. ft. ...	Timber, wrought and put up.
78 sq. ft. ...	¾" weather board including painting.
360 „ ...	Door shutter, ½ panelled and glazed.
84 „ ...	Doors, batten.
424 „ ...	Windows, glazed.
392 „ ...	Wire netting including frames, etc.
6,914 „ ...	Roofing with Mangalore tiles over flat tiles with air spaces.
1,536 „ ...	Levelling course of concrete.
4,800 „ ...	Paving with thin Cuddapah slabs over ½" mortar and pointing with Portland cement.
895 „ ...	Plastering with mortar, two coats.
1,548 „ ...	Painting, three coats, doors, windows, etc.
6,612 „ ...	Painting, two coats, to roof timbers.
4 No. ...	Galvanised iron buckets.
4 „ ...	Zinc spout.
4,848 sq. ft. ...	22 B. W. G. corrugated iron sheet walling including necessary bolts, etc., complete with painting, two coats, (interior white and exterior grey).
	Contingencies at 5 per cent.
	Petty supervision at 2½ per cent.
	Total Rs...

Epidemic Disease Shed: Plates 91 And 92.

In the above plates is illustrated the type design No. 147 issued with proceedings of the Madras Sanitary Board, No. 599-S., dated 20-9-1913. The specification report which accompanied this design was as follows: Foundations: A depth of 3' 0" has been provided for pillars and walls of latrine, of which the bottom 1' 6" will be concrete broken brick in lime mortar and the rest brick in lime mortar. The foundations of the retaining wall between pillars will be of brick in lime mortar 1' 6" deep. Basement will be of brick in lime mortar, 1' 6" high. Walling will be of bamboo tatties secured to wooden frames, fixed to pillars which will be of brick in lime mortar. Swing shutters of galvanized iron sheets in wooden frames are provided below the tatty screens. They should be secured when open by buttons fixed to the frames of the tatties. Cutstone work: Templates have been provided under the bearings of trusses. Woodwork: One of the timbers mentioned in Circular No. 2040 C., dated 27th April 1909, as applicable to Table II of Circular No. 234 C., dated 9th January 1908, should be used. Roofing throughout will be of flat and pan tiles on teak reepers. Flooring throughout will consist of $\frac{3}{4}$" cement rendering over 4" concrete. Finishing: The bottom of the tatties will be tarred to a height of 3' 0" and the remaining portions whitewashed. The wooden frames of tatty walls above a height of 3' 0" and all trusses and roof timbers will be painted with two coats of approved paint. The basement wall all round will be plastered with $\frac{1}{2}$" Portland cement. The pillars will be plastered with two coats of lime mortar. Cost: The building shown on the drawings is estimated to cost from Rs. 4,500 to Rs. 6,750 according to locality. NOTE: Floor: Any patent stone on concrete. 4'×4'×1'-6" concrete bed under each pier. Wooden trusses are provided at the ends instead of iron, for convenience in fixing tatties or Lammit sheets in the gable ends.

A: Door, bamboo mat with wooden frames ... ... 6'-0"×6'-8".
B: Door, bamboo mat with wooden frames ... ... 2'-6"×6'-6".
C: Door, bamboo mat with wooden frames ... ... 3'-6"×6'-6".

Abstract Of Quantities For An Epidemic Disease Shed: Plates 91 and 92.

Quantity.	Description of work.
1,567 c. ft.	Excavation for foundations.
1,433 „	Filling in basement with earth.
715 „	Concrete, broken brick in lime mortar.
1,196 „	Brick in lime mortar (foundations and basement).
654 „	Brick in lime mortar (superstructure).
21 „	Cutstone work.
360·16 „	Timber, wrought and put up.
3,242 lbs.	Wrought-iron work.
2,555 sq. ft.	Roofing with flat and pan tiles including teak reepers complete.
1,230 „	Levelling course of concrete, 4" thick.
1,401 „	Rendering with $\frac{3}{4}$" Portland cement.
292 „	Ventilators with swing flaps of galvanized iron sheets including frames and fittings, complete.
181 „	Bamboo tatty doors including battens and fittings, complete.
1,874 „	Bamboo tatty walls with necessary reepers including fixing, complete.
2,101 „	Tarring, two coats.
4,265 „	Whitewashing, 2 coats.
3,846 „	Painting, 2 coats, of approved paint.
450 „	Plastering with Portland cement, $\frac{1}{2}$" thick.
1,409 „	Plastering with lime mortar, 2 coats.
270 r. ft.	Concrete drain including, cement plastering.
60 sq. ft.	Galvanized, sheet iron.
	Contingencies at 5 per cent.
	Petty supervision at $2\frac{1}{2}$ per cent.
	Total Rs...

BUILDINGS: MAIN DETAILS OF CONSTRUCTION OF MARKETS AS ...ED FROM A STUDY OF PLANS.

e ground leve... ve the floor of the shed...

Mufassa... d with Cuddapah slab ...oring ... of 1 in 72 from the centre toward

In the ... while the passage will be floored with p... designs N... e rendered with ½" ... with proceedings ... with a similar slope to ... o. 722-S., dated 15-8-... Bodie ... the passage ... port which accompanied ... designs ... ws: Typical site plans: Three typical s... accompany ... plates 99,100 and 101) have been drawn out and show three different arrangements of the market stalls in accordance with the presumed limitations of different sites. The first two plans, plates 99 and 100 are intended for a site bounded on all four sides by a road. The third plan, plate 101, is intended to show how a small or subsidiary market containing only grain, condiment and vegetable stalls can be arranged. The third proposal is based on an actual case which arose in connection with the construction of a small market at Madura. Points to be observed in connection with the selection of a site for a market of any small municipal town: Site: The site for a market should be located in the first instance with due regard to the convenience of the people. A number of markets have not been successful, because the site was either badly chosen or when the new market was constructed the old and insanitary market belonging to private owners was allowed to continue. The obvious policy for a Municipal Council to follow is first of all to acquire the private market or to close it under their powers before they open a new market constructed on sanitary lines. Then the site for the market should be if possible on a main road and if finances permit in acquiring the site the whole block surrounded by four roads should be acquired in the first instance even although the market as first built does not occupy the whole of this site. It is needless to add that the site should be as sanitary as possible. It should not be lowlying or if lowlying it should be capable of being raised and drained. The site should therefore be so situated that watersupply and drainage arrangements can be added. Arrangements of the buildings: If a market is constructed with its principal side facing the main road, it will be found financially advantageous to construct the grain or condiment bazaars also facing this main road and not facing the inside of the market. The reason for this is that these grain and condiment bazaars are not only limited in number but a comparatively high rent can be obtained for them thus adding to the income of the market. The main entrance to the market should be facing this main road and it has been found by personal inspection that two additional small entrances at each end of the market enclosure, as shown in the three typical site plans, plates 99, 100 and 101, are required for the convenience of the people who patronise the grain and condiment bazaars. The first enclosure in the market, as shown in plate 99, is surrounded by grain and condiment bazaars and the central portion is occupied by four or more blocks of vegetable stalls. The whole of this enclosure therefore does deal only with vegetarian products, and in this way meets the wishes of a large number of people. At the back of the first enclosure there will be an iron gate to provide a nominal cut off from the second enclosure which will contain the fish and mutton stalls. The entrance for fish and mutton bazaars' stall-holders into the second enclosure will be from the road at the back and there will be no occasion for these products being carried through the first enclosure or vegetable market before exposure in the fish and mutton stalls in the second enclosure. If it so happened that it was impossible to obtain the side or the back roads, then in such a case, plate 100 shows the arrangement suggested. Although in this plan roads are shown on all four sides of the market enclosure yet all that would be required to provide a suitable market according to this plan would be to open conservancy lanes one at each end of the site and the market itself would face a main road and there would be no back road at all. In this arrangement the mutton and fish stalls are shown to one side of the vegetable market and are practically independent of it. The third plan, plate 101, shows the arrangement for providing grain and condiment stalls with a few vegetable stalls only and is really intended to illustrate a small subsidiary market. Market entrance: It is considered that the market entrance to a market of any importance should be emphasised by the construction of a suitable entrance to the market. Two alternative designs have been drawn up by the Consulting Architect to Government (Mr. Nicholls) and are shown in plates 102 and 103. Plan, plate 103, shows the entrance provided with a clock tower and an office room on the first floor. Plan, plate 102, simply shows a market entrance with two rooms, one on each side of the entrance of the gateway. This plan will usually be adopted by municipalities. Plates 104 and 105

show details of the clock tower entrance illustrated in plate 103. Grain and condiment bazaars: These designs are illustrated in plates 106, 107 and 108. In the condiment bazaar, the corner of the market is illustrated in plate 109. The general idea of a grain and condiment bazaar consists of a room for storing grain or condiments provided with removable plank shutters and a ventilator protected by expanded metal of small mesh in the back wall. In the roof there is a small dormer ventilator also provided with expanded metal. The walls are constructed of masonry and the floor is constructed of $1\frac{1}{2}''$ Cuddapah slabs with concrete underneath. The roof is constructed of Mangalore tiles with close fitting Mangalore ceiling tiles. The shutter of the door is the only portion of the building through which rats might readily gain access and in order to prevent this and to discourage the making of holes through the plank shutters, zinc sheets, 9″ wide are screwed on to both top and bottom of the plank shutters. The ventilator in the roof is protected by expanded metal of smallest mesh so as to prevent the ingress of rats. In front of this store room there is a display platform and in front of this display platform there is a covered verandah for buyers. Vegetable bazaars: The vegetable bazaar type design is shown in plates 111 and 112 and consists of a shed provided with Mangalore tiled roof supported on pillars and masonry gables with suitable arched openings. The arrangement of the vegetable stall consists of a platform $6' \times 6'$ for each stall-holder and a store room $8'\,6'' \times 6'$ for storing fruit or vegetables overnight. This store room is made of expanded metal on a wooden frame so that it is very efficiently ventilated and the design shown in plates 111 and 112 is of a new type as far as Madras Presidency is concerned. It was found on a joint inspection by the Surgeon-General Bannerman, Major Justice, the Sanitary Commissioner, and Mr. Hutton, the Sanitary Engineer, that the stall-holders insist on having rooms for storing vegetables at least for one night and it was accordingly decided to provide an expanded metal store room as now shown in this plan. It was also considered that all that was required for the stall-holder was a simple platform with polished Cuddapah slab as the local custom apparently insists on the vegetable and fruit being placed either on such a platform or on the middle of the passage of the vegetable stall itself. During an inspection of an upcountry market in an important town it was found that the passage of the building was being used for the display of vegetables and fruit and the people had to use the road on the outside of the building instead of the passage which was intended for them. The result of this inspection is the design shown in plates 111 and 112. The floor of the building is Cuddapah slab over concrete. These Cuddapah slabs are unpolished, the only polished Cuddapah slabs in the building being the platform for display of vegetables. The whole of the building is capable of being washed out by means of a hose. The building is also provided with a ridge ventilator and in order to ... ws expanded metal is suitab amboo mat with wooden ilator. Mutton an frames ... in plate 110
Door, with wooden t inspection
re frames ... 3′ design for
mutton and **For An Epide** novation
about it that the **Plates** 92.
as well as for ought
out at the joint ins ne de ty of so
constructing mut Descrip that there would be no inconvenient between the stall-holder and the buyer. This has been obtained by using king post trusses for the building. The tie beam will support an iron rod on which chains and hooks for the suspension of carcasses can be provided. The only difference between the mutton and beef arrangements would be that the chains and hooks would be smaller in the case of mutton and the chains would also be longer. The design of mutton and beef stalls consists of a passage 6 feet wide for buyers and platforms 6 feet square for the display of meat. On each platform there is a chopping block. In the actual plan this block is shown on the right of the platform. But a perusal of the section will show that the block is a removable one and can be placed on any part of the platform which the stallholder may by local custom desire. The building is also provided with a ridge ventilator, the ridge ventilator being covered in with expanded metal to prevent crows entering the building. For the same reason the verandah of the building between masonry pillars which support the trusses is filled in with expanded metal, suitable openings being left as shown in the elevation. The building is also provided with two gables with arched openings. Fish stall: The fish stall, shown in plate 113, is somewhat similar in design to the mutton and beef stalls. It consists of a 6 feet passage for buyers and platforms measuring $5' \times 3'$ for the display of fish. The top of these platforms consists of polished Cuddapah slabs and the platforms themselves only project 9″ above the floor level. The seller is supposed to sit behind the platform. Between the two rows of stalls an expanded metal partition is provided so as to allow free perflation of air and the spaces between verandah pillars are filled in with expanded metal. Water supply and drainage arrangements: One of the most important requirements of a market is a suitable supply of water under pressure. This water is not only required for drinking purposes for those who are attending the market, but is also required for market purposes. In addition, it is

necessary to provide each stall with two hydrants and a suitable length of hose so that the stalls can be flushed out daily. This particularly refers to the vegetable, mutton, beef and fish stalls. The water supply to a market should be provided from the pipe main. B ground level is absent one of the type desi the floor of the shed fitted with pumps and e d with Cuddapah slab flooring for such a mark of 1 in 72 from the centre towards h stall consile the passage will be floored with slab sides. T e rendered with ½" cem stall and the with a similar slope to ied away into a muni Bodies ge with road. Where no drainage ion report accompanying a small municipal town th s: 1 is a r should be accommodate 48 dhob or a pipe sewer to a well, pumping arr where the sullage should be trea taps, rooms for Where neither method is possib inage system. circumstances, a cesspool arrangement of water per day approved by the Sanitary Board sho will require (48 × 250 Conservancy: The complete h day from a health point of view is c site nd when the conservancy arrangements are su ater sfully carried out. These arrangements consist i mo e hosing of vegetable and meat and fish stalls ner. y and the flushing of all drains; also in the d 16 t weeping up of all garbage and rubbish and its gall val from the site of the market. It is also nec will ry to employ one or two or more sweepers who u der the direction of the market overseer would remove certain rubbish when its immediate removal was desirable and could be accomplished without interfering with the convenience of those attending the market. For the convenience of those attending the market there should be suitable urinals and latrines suitably located. These conveniences should be on the water carriage system when the drainage system of the town so permits. When the latrines and urinals are on the ordinary system necessitating frequent cleansing such a requirement as the attention of the sweeper at least twice daily or oftener if necessary should be one of the principal duties of supervision required from the market overseer. Without such daily attention and also immediate replacement of damaged pans the dry system of conservancy can be nothing more than a nuisance. When it is however supervised on which its success obviously depends the system will be found to be fairly efficient and suitable for towns which cannot afford more expensive methods of conservancy.

Abstract Of Quantities For Market Main Entrance: Plate 102.

Quantity.	Description of work.
4,125 c. ft.	... Earthwork excavation.
235 „	... Filling in basement with clean sand.
1,889 „	... Concrete, broken brick in lime mortar.
1,723 „	... Brickwork in lime mortar with ordinary bricks.
4,724 „	... Table-moulded face bricks with ordinary bricks in lime mortar.
53 „	... Archwork in table-moulded brick.
246 „	... Archwork in cutstone.
126 „	... Cutstone work.
3,353 sq. ft.	... Plastering with chunam, two coats.
1,875 „	... Pointing with Portland cement.
503 „	... Flooring with 1½" Cuddapah slab on 4" concrete and pointed with cement to the full depth of slab.
321 „	... Flooring with gravel, 6" thick.
159·91 c. ft.	... Teakwood, wrought and put up.
35 lb.	... Wrought-iron work.
1,650 sq. ft.	... Roofing with Mangalore tiles with flat ceiling tiles, etc., complete.
72 „	... Doors, panelled with frames, iron fittings, hinges, etc., complete.
96 „	... Windows with batten shutters and iron bars, frames and fittings.
1,761 „	... Painting with Imperial zinc white, two coats.
378 „	... Painting with chocolate, two coats.
No. 4.	Mangalore tiled sunshades with teak supports, etc., complete.
No. 1.	Ornamental iron gate with hinges, bolts, rollers, etc., complete.
No. 2.	Finials, cutstone, large.
No. 4.	Do. small.
No. 2.	Do. wooden, teak.
64 r. ft.	... Barge board, teak.
79 „	... 6 inch concrete drain with 9" × 4" cut stone coping and 1' 6" × 1½" Cuddapah slab pavement including ½" cement plastering, etc., complete.
	Petty supervision at 2½ per cent.
	Tools and plant at 5 per cent.
	Contingencies at 5 per cent.
	Total Rs...

Abstract Of Quantities For Market Entrance Plates 103, 104 And 105.

Quantity.	Description of work.
2,888 c. ft	... Excavating foundation.
1,812 „	... Concrete, broken brick in lime mortar.
659 „	... Brickwork in lime mortar.
538 „	... Brick in lime mortar faced with table-moulded brick for basement.
2,722 „	... Brick in lime mortar faced with table-moulded brick in superstructure.
23 „	... Archwork, brick in lime mortar.
146 „	... Archwork, cutstone.
336 „	... Cutstone work.
69·75 „	... Teakwood, wrought and put up.
819 sq. ft	... Terrace flooring with brick on edge, 3" concrete, three courses of flat tiles and plastering the ceiling, etc.

Quantity.	Description of work.
316 sq. ft. ...	Flooring with Cuddapah slab, 1½" thick, over 10" sand bedding and pointing with Portland cement.
2,453 " ..	Pointing with prepared mortar (exterior).
1,574 " ...	Plastering with chunam, two coats (interior).
64 " ...	Teak panelled doors with frames, bolts, hinges, etc.
38 " ...	Teak panelled windows with frames, bolts, hinges, etc.
6 " ...	Teak ventilators, glazed with frames, etc.
25 " ...	Paving with 1½" Cuddapah slab over ½" lime mortar and pointed with Portland cement.
753 " ...	Wood-oiling, two coats.
92 " ...	Painting, zinc white, two coats.
13·17 cwt. ...	Rolled steel girders.
1 No. ...	Iron gate, ornamental.
L.S. ...	Gravelling the entrance.
L.S. ...	Hoisting the girder.
2,402 c. ft ...	Brick in lime faced with stock table-moulded brick in superstructure.
19 " ...	Archwork, brick in lime faced with stock table-moulded brick.
300 " ...	Cutstone work.
149 " ...	Teakwood, wrought and put up.
238 lbs. ...	Wrought-iron work.
1,417 sq. ft. ...	Roofing with Mangalore tiles and flat tiles over teak reepers.
129 " ...	Terracing with brick on edge, 3" concrete, three courses of flat tiles, top and ceiling plastered.
2,901 " ...	Plastering with chunam, two coats.
1,615 " ...	Pointing outside with prepared mortar.
95 r. ft. ...	Cornice work.
96 sq. ft. ...	Teak panelled doors, with frames, bolts, hinges, etc., complete.
38 " ...	Teak panelled windows with frames, bolts, hinges, etc., complete.
44 " ...	Ventilators, glazed with frames, etc.
2,014 " ...	Wood-oiling, two coats.
128 " ...	Painting with zinc white, two coats.
3·93 cwt. ...	Rolled steel girders.
56 r. ft. ...	Drain, lead sheeting with woodwork with galvanized strengthening bar.
104 " ...	Rain water zinc pipes, 4" diameter, including hooks and fixing, etc.
L.S. ...	Staircase with Stringer's landing, hand rail including varnishing, etc.
L.S. ...	Hoisting the girder.
	Petty supervision, 2½ per cent.
	Tools and plant, 5 per cent.
	Contingencies, 5 per cent.
	Total Rs...

Abstract Of Quantities For Grain And Condiment Bazaar (Five Stalls): Plate 106.

Quantity.	Description of work.
2,404 c. ft. ...	Earthwork, excavation foundations.
2,325 " ...	Concrete, broken brick in chunam.

Quantity.	Description of work.
3,725 c. ft. ...	Brickwork in chunam 1st and 2nd sort mi...
20 "	... chunam.
5,425 sq. ft.	..., two coats.
1,1...	...ah slab on 4" ... with cement.
1,	...les over flat ...
163 " ...	... shutters,
No. 10 ...	Do ... anded
1 c. ft. ...	C...
152·77 " ...	T...
1,789 sq. ft. ...	F...
No. 2 ...	F...
170 r. ft. ...	6... all round the
23 sq. ft.	...spension of ca...ilators with expanded
	...pervision at 2½ per cent.
	...nd plant at 5 per cent.
	...ingencies at 5 per cent.
	Total Rs...

...amboo mat with wooden
frames ... ...
Door, b...bo... mat with wooden
frames ... ...
...uantities For An Epid...
...d: Plates 9... 92.
Descrip...
...ne des...
...that there
...between the st... up.
This has been obtained
for the building. ...
iron rod on which
...only difference bet...
arrangements would b...
...alle...
...o be...
...alls
and
heat.
Ir...
...sec...

Abstract Of Quantities For Grain And Condiment Bazaar Of Four Stalls: Plate 107.

Quantity.	Description of work.
1,811 c. ft. ...	Earthwork excavation.
1,725 " ...	Concrete in vitrified brick in chunam.
2,274 " ...	Brick, 1st and 2nd sort, mixed or uncoursed rubble stone in chunam.
726 sq. ft. ...	Flooring with 1½" Cuddapah slab and pointed with cement to the full depth of slab.
1·12 c. ft. ...	Cutstone work.
3,068 sq. ft. ...	Plastering with chunam, two coats.
112 c. ft. ...	Teakwood, wrought and put up.
1,271 sq. ft. ...	Roofing with Mangalore tiles on flat tiles including teak reepers and imbedded in mortar.
130 " ...	Teakwood doors with frames, shutter planks including zinc sheet covering at top and bottom of planks, etc., complete.
18 " ...	Teakwood expanded metal ventilator with frames, etc.
1,597 " ...	Painting chocolate, 2 coats.
No. 2 ...	Iron finials.
" 4 ...	Ventilating tiles.
1,385 c. ft. ...	Filling in basement with sand.
136 r. ft. ...	6" concrete drain, 9"×4" cutstone coping with 1½'×1½" Cuddapah slab pavement including ½" cement plastering, etc., complete.
	Petty supervision at 2½ per cent.
	Tools and plant at 5 per cent.
	Contingencies at 5 per cent.
	Total Rs...

Abstract Of Quantities For Grain And Condiment Bazaar: Plate 108.

Quantity.	Description of work.
1,710 c. ft.	[illegible]
1,636 "	[illegible]
1,914 "	[illegible]
2,244 sq. ft.	[illegible]
557 "	[illegible] ...uddapah slab on 4" ... pointed with cement to the slab.
1,23[illegible] "	[illegible] ...galore tiles over flat ...k reepers.
130 "	[illegible] ...mes, shutters with ... at top and bottom ... lock, key, etc.,
18 "	... [illegible] frames and fixed ... complete.
No. 4	... Ventilat[illegible]
108·45 c. ft.	... Teak timber, [illegible]
1 "	... Cutstone work [illegible]
1,424 sq. ft.	... Painting wood[illegible]
138 r. ft.	... 6" semi, oval [illegible] ...ns.
No. 2	... Finials.
	Petty supervisi[on at] 2½ per cent.
	Tools and plan[t at ...] per cent.
	Contingencies, [at ... pe]r cent.
	Total Rs...

Abstract Of Quantities For Market Front Corner: Plate 109.

Quantity.	Description of work.
705 c. ft.	... Earthwork, excavation.
361 "	... Filling in basement with clean sand.
367 "	... Concrete, broken brick in lime mortar.
219 "	.. Brickwork in lime mortar.
1,025 "	... Brickwork, table-moulded, in lime mortar.
164 "	... Cutstone work.
550 sq. ft.	... Plastering with chunam, two coats.
563 "	... Pointing in cement.
151 "	... Flooring with 1½" Cuddapah slab on 4" concrete pointed with cement to the full depth of the slab.
21 "	... Cuddapah slab, 1½" thick and pointed with cement.
22 r. ft.	... Brick cornice.
281 sq. ft.	... Roofing with Mangalore tiles with flat tile ceiling including teak reepers.
23·58 c. ft.	... Teakwood, wrought and put up.
33 sq. ft.	... Door with teak frames, planks, bolts, etc., complete.
28 "	... Windows with teak frames, iron bars, venetian shutters, hinges, bolts, etc., complete.
3 "	... Louver ventilator.
430 "	... Painting, two coats, of chocolate paint.
11 r. ft.	... Brick cornice work.
No. 2	... Cutstone pinnacles including base stones over gables.

Quantity.	Description of work.
No. 1	... Cutstone pinnacle including base stone over pillar.
No. 2	... Teakwood sun shades with painting, etc., complete.
25 r. ft.	... 6" concrete drain with 1' 6"×1½" Cuddapah slab pavement and 9"×4" cutstone coping including ½" cement plastering, etc., complete.
	Tools and plant, 5 per cent.
	Petty supervision, 2½ per cent.
	Contingencies, 5 per cent.
	Total Rs...

Abstract Of Quantities For Mutton And Beef Stalls: Plate 110.

Quantity.	Description of work.
1,758 c. ft.	... Earthwork, excavating foundations.
1,306 "	... Concrete, broken brick in chunam.
1,458 "	... Brickwork in chunam.
1,907 sq. ft.	... Plastering with chunam.
542 "	... Plastering with cement, ½" thick.
61 c. ft.	... Archwork, brick in chunam.
1,635 sq. ft.	... Flooring with Cuddapah slab, 1½" thick, on 4" of concrete.
10 c. ft.	... Cutstone work.
2,675 sq. ft.	... Roofing with Mangalore tiles over flat tiles including teak reepers.
1,378 "	... Expanded metal partitions including teak frames, etc., complete.
274·37 c. ft.	... Teakwood, wrought and put up.
No. 2	... Finials.
196 r. ft.	... 6" semi-oval drain, complete.
3,284 sq. ft.	... Painting woodwork.
346 lb.	... Ironwork.
	Ironwork for fixing trusses, etc.
No. 14	... Removable chopping blocks.
460 c. ft.	.. Sand filling.
84 r. ft.	... Cornice.
	Petty supervision at 2½ per cent.
	Tools and plant at 5 per cent.
	Contingencies at 5 per cent.
	Total Rs...

Abstract Of Quantities For Vegetable Bazaars Of Seven Pairs Of Stalls: Plates 111 And 112.

Quantity.	Description of work.
3,292 c. ft.	... Earthwork, excavation.
2,322 "	... Concrete in vitrified brick in chunam mortar.
3,289 "	... Brick in chunam mortar or uncoursed rubble stone in chunam mortar.
2,083 sq. ft.	... Plastering with chunam, two coats.
443 "	... Plastering with cement, ½" thick, 1 : 2.

Quantity.	Description of work.
504 sq. ft.	... Flooring with 1½" polished Cuddapah slab and pointed with cement to the full depth of slab.
1,923 „	... Flooring with 1½" unpolished Cuddapah slab and pointed with cement to the full depth of slab.
9 c. ft.	... Cutstone work.
100 r. ft.	... Cornice work.
374 c. ft.	... Teakwood, wrought and put up.
2,899 sq. ft.	... Painted expanded metal ⅜" mesh and $\frac{1}{32}$"×186 with teakwood frames including fixing, etc., complete.
210 „	... Painted expanded metal door including frames, hinges, etc., complete.
3,736 „	... Roofing with Mangalore tiles on flat tiles including teak reepers, chunam borders, etc.
9,050 „	... Painting chocolate, two coats.
824 lb.	... Wrought-iron work.
No. 2.	... Iron finials.
1,327 c. ft.	... Filling in basement with clean sand.
140 r. ft.	... 6" concrete drain with 9"×4" cutstone coping and 1'—0"×1½" Cuddapah slab pavement including ½" cement plastering, etc., complete.
	Petty supervision at 2½ per cent.
	Tools and plant at 5 per cent.
	Contingencies at 5 per cent.
	Total Rs...

Abstract Of Quantities For Fish Stalls: Plate 113.

Quantity.	Description of work.
1,232 c. ft.	... Earthwork, excavating foundations.
825 „	... Concrete, broken brick in lime mortar.
1,069 „	... Brickwork in chunam.
61 „	... Archwork.
1,726 sq. ft.	... Plastering with chunam.
121 „	... Plastering with cement, ½" thick.
1,201 „	... Flooring with Cuddapah slab, 1½" thick, on 4" of concrete.
210 „	... Polished 1½" Cuddapah slab.
11 c. ft.	... Cutstone work.
2,394 sq. ft.	... Roofing with Mangalore tiles over flat tiles including teak reepers.
1,221 „	... Expanded metal partitions including teak frames, etc., complete.
227·46	... Teakwood, wrought and put up.
No. 2	Finials.
190 r. ft.	... 6" semi-oval drain.
2,803 sq. ft.	... Painting woodwork.
	Ironwork for fixing trusses.
	Petty supervision, 2½ per cent.
	Tools and plant, 5 per cent.
	Contingencies, 5 per cent.
	Total Rs...

Mufassal Markets: Plates 114 To 119.

In the above plates is illustrated type design No. 40 issued with proceedings of the Madras Sanitary Board, No. 514-S., dated 13-7-1897. No specification report accompanied this design. The general disposition of the different stalls comprising the market is shewn in plate 114. The detailed plans of the Market [illegible] Mutton stalls, Beef stalls, Fish [illegible] mat with chun[illegible] Condiment stalls, Veget[illegible] two etc., are given in Door, [illegible] bo[illegible] mat with wooden frames ... ...les [illegible] Stalls:

[illegible] Quantities For An [illegible] shu[illegible] [illegible]: Plates [illegible] 32.

Quantity.	Description of work.
867 c. ft.	... [illegible] that there
744 „	... [illegible] between the [illegible] up.
738 „	... [illegible] has been obtain[illegible]
1,033 „	... [illegible] the building. [illegible]
1,031 sq. ft.	... [illegible] rod on which [illegible] ing.
899 „	[illegible]
122	[illegible] k, wrought and put up.
[illegible]	only difference be[illegible]
1,349 sq. ft.	[illegible] with Mangalore tiles.
	[illegible] supervision, 2½ per cent.
	[illegible] and plant, 5 per cent
	[illegible] gencies, 5 per cent.
	Total Rs...

Abstract Of Quantities For Beef Stalls: Plate 116.

Quantity.	Description of work.
596 c. ft.	... Earthwork, excavation.
439 „	... Do., filling in.
415 „	... Concrete in chunam.
1,035 „	... Brick in chunam.
56 „	... Archwork.
1,505 sq. ft.	... Cement plastering.
466 „	.. Flooring with Cuddapah slabs.
39 c. ft.	... Woodwork, wrought and put up.
185 sq. ft.	... Wire netting in frames.
186 l. ft.	... Railposts and bressummers including bolts, etc , complete.
1,100 sq. ft.	... Roofing with Mangalore tiles.
	Petty supervision, 2½ per cent.
	Tools and plant, 5 per cent.
	Contingencies, 5 per cent.
	Total Rs...

Abstract Of Quantities For Fish Stalls: Plate 117.

Quantity.	Description of work.
1,122 c. ft.	... Earthwork, excavation.
713 „	... Do. filling in.
646 „	... Concrete in chunam.
1,320 sq. ft.	... Brick in chunam.

Quantity.	Description of work.
830 sq. ft.	... Flooring with Cuddapah slabs.
1,609 ,,	... Cem[illegible]
117 c. ft.	... W[illegible] up.
1,160 sq. ft.	.. [illegible]
L. S.	. [illegible]
	Total Rs...

Abst[illegible] Grain And [illegible]te 118.

Quantity.	Description of work.
2,489 c. ft.	... Earthwork, ex[illegible]
2,672 ,,	... Do., fil[illegible]
1,665 ,,	... Concrete in chu[illegible]
6,519 ,,	... Brick in chunam[illegible]
367 sq. ft.	... Cement plasteri[illegible] basement only.
6,911 ,,	... Chunam plaster[illegible]
171 c. ft.	... Woodwork, wro[illegible] and put up.
2,700 sq. ft.	... Roofing with M[illegible]ore tiles.
504 ,,	... Doors.
48 ,,	... Ventilators.
	Petty supervisio[illegible] per cent.
	Tools and plant, [illegible] cent.
	Contingencies, 5 pe[illegible]cent.
	Total Rs...

Abstract Of Quantities For Vegetable Stalls: Plate 119.

Quantity.	Description of work.
1047 c. ft.	... Earthwork, excavation.
1463 ,,	... Earthwork, filling in.
907 ,,	... Concrete in chunam.
1113 ,,	... Brick in chunam.
28 ,,	... Archwork.
1365 sq. ft.	... Cuddapah slab flooring.
842 ,,	... Cement plastering.
105 ,,	... Wire-netting in frames.
68 c. ft.	... Woodwork, wrought and put up.
864 sq ft.	... Roofing with Mangalore tiles.
372 l. ft.	... Iron rails including bolts etc., complete.
	Petty supervision, 2½ per cent.
	Tools and plant, 5 per cent.
	Contingencies, 5 per cent.
	Total Rs...

Abstract Of Quantities For Platform For Fuel, Grass Etc: Plate 119.

Quantity.	Description of work.
309 c. ft.	... Earthwork.
552 ,,	... Concrete in chunam.
155 ,,	... Brick in chunam.
70 sq. ft.	... Cement plastering.
1000 ,,	... Cuddapah slab flooring.
	Petty supervision, 2½ per cent.
	Tools and plant, 5 per cent.
	Contingencies, 5 per cent.
	Total Rs...

Weekly Market Sheds For Mufassal Stations: Plates 120 To 124.

In the above plates are illustrated the type designs Nos. 70, 71 and 72 issued with proceedings of the Madras Sanitary Board, No. 579-S., dated 6-10-1898. The shed shewn in plate 120 measures 58 feet × 20 feet, outside dimensions. The estimated cost varies from Rs. 710 to Rs. 1,015, or Rs. 1,020 to Rs. 1,530, according to the locality and the materials used. The shed shewn in plates 121 and 122 measures 47 feet 1½ inches × 17 feet 3 inches, outside dimensions. The estimated cost varies from Rs. 690 to Rs. 1,035; or Rs. 940 to 1,410, according to the locality and the materials used. The shed shewn in plates 123 and 124 measures 47 feet 1½ inches × 17 feet 3 inches, outside dimensions. The estimated cost varies from Rs. 880 to Rs. 1,320 according to locality. No specification report accompanied the above type designs.

Abstract Of Quantities For A Weekly Market Shed For Mufassal Stations: Plate 120.

Quantity.	Description of work.
	Larger Shed.
599 c. ft.	... Earthwork.
451 ,,	... Filling in basement.
799 ,,	... Masonry, brick in chunam.
423 sq. ft.	... Plastering with cement, ¾".
3 c. ft.	... Cutstone.
154 ,,	... Woodwork, wrought and put up.
1,769 sq. ft.	... Roofing with Mangalore tiles and teak reepers.
2,091 ,,	... Wood-oiling.
	Contingencies.
	Total Rs...
	Alternative design with cheap materials: Brick in mud, chunam plastering and junglewood.
599 c. ft.	... Earthwork.
451 ,,	... Filling in basement.

Quantity.	Description of work.
799 c. ft. ...	Masonry, brick in mud.
423 sq. ft. ...	Plastering with chunam.
3 c. ft. ...	Cutstone.
154 „ ...	Woodwork, junglewood.
1,769 sq. ft. ...	Roofing with Mangalore tiles and teak reepers.
	Contingencies.
	Total Rs...

Abstract Of Quantities For A Weekly Market Shed For Mufassal Stations: Plates 121 And 122.

Quantity.	Description of work.
	(*a*) For rail posts and corrugated roofing.
284 c. ft. ...	Excavation.
385 „ ...	Filling in basement.
472 „ ...	Masonry, brick in chunam.
373 sq. ft. ...	Plastering with cement.
140 r. ft. ...	S.I. rails.
509 lb. ...	Angle iron.
526 „ ...	Tie rods, bolts, &c.
48 c. ft. ...	Woodwork, wrought and put up.
5·29 sq. ft. ...	Wood-oiling (two coats).
12·75 „ ...	Corrugated iron roofing.
	Contingencies, 5 per cent.
	Total Rs...
	(*b*) Teakwood posts and Mangalore roofing.
467 c. ft. ...	Excavation.
266 „ ...	Filling in basement.
623 „ ...	Masonry, brick in chunam.
3·93 sq. ft. ...	Plastering with cement.
154·0 c. ft. ...	Woodwork, wrought and put up.
19·25 sq. ft. ...	Wood-oiling (two coats).
264 lb. ...	Tie rods, &c., for truss.
12·12 sq. ft. ...	Roofing with Mangalore tiles including reepers, &c.
	Contingencies.
	Total Rs...

Abstract Of Quantities For A Weekly Market Shed For Mufassal Stations: Plates 123 And 124.

Quantity.	Description of work.
284 c. ft. ...	Excavation for foundation.
385 „ ...	Filling in basement.
471 „ ...	Masonry, brick in chunam.
373 sq. ft. ...	Plastering with cement.
140 r. ft. ...	S.I. rails for posts.
605 lb. ...	Iron work for tie-rods, &c.

Quantity.	Description of work.
114 c. ft. ...	Teakwood, wrought and put up.
1,212 sq. ft. ...	R[illegible] Mangalore tiles including [illegible] mat with chun[illegible], tw[illegible]ers.
1,613 [illegible] ...	[illegible] ah cent.
Door, [illegible] bo[illegible] mat with woode[illegible] frames ...	...[illegible]les
	Total Rs...

[illegible]uantities For An [illegible] Weekly Ma[illegible]d: Plates [illegible]

In the above [illegible] andsigns of Weekly markets [illegible] Nowroji, now Sanitary [illegible] that there [illegible] nment of Madras, for certa[illegible] between the s[illegible] esidency of Madras. His [illegible]s has been obtain[illegible] accompanying these designs [illegible] the building. [illegible] The design for a weekly mar[illegible]on rod on which vegetable, grain and condi[illegible]suspension of [illegible] mutton and beef stalls and [illegible] difference be[illegible]rials and principles of construction. G[illegible]ld [illegible] Foundation: The foundations provided are th[illegible]imum required for hard soil. They should be [illegible] red to suit the nature of the soil at site. Mas[illegible] The structures are designed for brick masonr[illegible] any local building material may be employe[illegible] in such case the thickness of walls should be [illegible] ered to suit. Flooring: The stalls should inv[illegible]bly be floored with an impervious material. Roofing timber: Any one of the timbers mentioned in Circular No. 2040-C., dated 29-4-09 as applicable to Table I of Chief Engineer's Circular No. 234-C., dated, 9-1-08, may be used. Finishing: The exterior and interior of the stalls should be finished off with ½″ cement plaster. Vegetable stalls, (vide plate 125): The stalls will measure 81′-0″×10′-0″ and will accommodate 8 vendors. The rear and the two ends are closed by masonry pillars and walls with an arched opening 4′ wide and 6′ high in the end walls. The stalls will be roofed with either Mangalore tiles, country tiles or corrugated iron on teak reepers and teak rafters as detailed in the section. The roof will be supported on masonry wall and teak posts on cutstone bases well imbedded in the masonry. The floor of the stall will be 1 foot above ground level, and consists of 4″ concrete plastered over with cement. The cost of the design at Madras rates for the 3 kinds of roofing shown on the design is as follows: Country tiled roof, Rs. 1,570. Managlore tiled roof, Rs. 1,400. Corrugated iron roof, Rs. 1,300. (Note: 20 B.W.G. Corrugated iron sheets should be used for roofing. This design may also be adopted for grain and condiment, etc., with the exception of meat, beef and fish). Meat or beef stalls, (vide plate 126): This design is considered sufficient for a weekly market. The building will accommodate 16 vendors and consists of an

open shed measuring $65'\text{-}10\frac{1}{2}'' \times 15'$ sub-divided into 16 raised platforms $5' \times 5' \times 6''$ high, for the display of meat or beef and a passage 4′ wide for the buyers. The two ends are closed with a masonry wall 6′ high. The floor of the shed will be 2 feet above ground level. The platforms will be 6″ above the floor of the shed. These will be provided with Cuddapah slab flooring with a gradient of 1 in 72 from the centre towards the sides, while the passage will be floored with 4″ lime concrete rendered with ½″ cement at ground level with a similar slope towards the drain. The sta Bodies in the passage will be roofed with Mangalo tion report accompanyin rs and rafters. The roof s: 1. This is a complet masonry pillars on the pla accommodate 48 dhobie n the passage. An iron rod well, pumping arra and 1″ for beef) will be let in taps, rooms for and bolted, on which the chains inage system. 2. ging the carcasses will be provided of water per day will be held in position by an iron will require (48 × 250) collar piece to prevent saggin h day. will be a chopping block in each stall w site a removable one and can be placed where ater e vendors may require. The cost of this design mo Madras rates is Rs. 3,480. Fish stall, (vide plat ner.): This design is the same as the meat and beef 16 fe with a platform $5' \times 3'$ raised 9″ above the floo galle he shed for the display of fish. The tops of the will latforms will be provided with polished Cuddapah abs. The cost of the design at Madras rates is Rs. 3,480. Water supply: Arrangements should be made for water supply to the market and this can be achieved by the construction of one or two type design wells or by improving the existing arrangements, if any, to conform to the latest sanitary principles, as this and the drains are the essential requirements for a market. Drainage: Open drains should be constructed all round the stalls and the discharge of the market washings should be taken to the nearest existing drain or to a cesspool constructed according to the latest design approved by the Sanitary Board.

Abstract Of Quantities For Weekly Markets: Plate 125.

Quantity.		Description of work.
		Vegetable stall with country tiled roofing.
467 c. ft.	...	Earthwork, excavating foundation.
311 „	...	Concrete, broken brick in chunam.
783 „	...	Table-moulded brick in chunam.
14 „	...	Semi-circular archwork, table-moulded brickwork in chunam.
1509 sq. ft.	...	Plastering with chunam, 2 coats.
1509 sq. ft.	...	Whitewashing, 2 coats.
611 „	...	Flooring with, 4″ thick, concrete and plastered over with cement, ½″ thick.
83 „	...	Plastering with cement, ½″ thick.
2 c. ft.	...	Cutstone, 2 line dressed.
119·61 „	...	Teakwood, wrought and put up.
1344 sq. ft.	...	Roofing with country tiles including teak reepers, chunam borders etc., complete.
395 c. ft.	...	Filling in basement with earth.
		Contingencies at 5 per cent.
		Supervision at 2½ per cent.
		Total Rs...
		Vegetable stalls with Mangalore tiled roofing.
467 c. ft.	...	Earthwork, excavation.
311 „	...	Concrete, broken brick in lime mortar.
183 „	...	Table-moulded brick in chunam.
14 „	...	Semi-circular archwork, table-moulded brick in chunam.
1509 sq. ft.	...	Plastering with cement, ½″ thick.
1509 „	...	Whitewashing, two coats.
611 „	...	Flooring with, 4″ thick, concrete and plastered over with cement ½″ thick.
83 „	...	Plastering with cement, ½″ thick.
2 c. ft.	...	Cutstone, 2 line dressed.
97·25 „	...	Teakwood, wrought and put up.
1344 sq. ft.	...	Roofing with Mangalore tiles on teak reepers including ridge tiles etc., complete.
395 c. ft.	...	Filling in basement with earth.
		Contingencies at 5 per cent.
		Petty supervision at 2½ per cent.
		Total Rs...
		Vegetable stalls with Corrugated iron roof.
467 c. ft.	...	Earthwork, excavating foundation.
311 „	...	Concrete, broken brick in mortar.
783 „	...	Table-moulded brick in chunam.
14 „	..	Semi-circular archwork, table-moulded brick in chunam.
1509 sq. ft.	...	Plastering with chunam, 2 coats.
1509 „	...	Whitewashing, two coats.
611 „	...	Flooring with, 4″ thick concrete and plastered over with cement, ½″ thick.
83 „	...	Plastering with cement, ½″ thick.
2 c. ft.	...	Cutstone, 2 line dressed.
75·19 „	...	Teakwood, wrought and put up.
1176 sq. ft.	...	Roofing with corrugated iron sheets, 20 B.W.G. including all fittings etc., complete.
395 c. ft.	...	Filling in basement with earth.
		Contingencies at 5 per cent.
		Petty supervision at 2½ per cent.
		Total Rs...

Abstract Of Quantities For Weekly Markets: Plate 126.

Quantity.	Description of work.
	Meat and beef stalls.
1,661 c. ft. ...	Earthwork, excavation.
1,616 „ ...	Filling in basement with clean sand.
242 „ ...	Concrete, broken brick in lime mortar.
1,878 „ ...	Brickwork in ordinary mortar.
5·06 „ ...	Cutstone work.
211·17 „ ...	Teakwood, wrought and put up.
552 lbs. ...	Wrought-iron work.
2,380 sq. ft. ...	Roofing with Mangalore tiles over flat tiles including teak reepers, etc., complete.
931 „ ...	Flooring with unpolished Cuddapah slab, 2" thick, and pointed with cement to the full depth of slab.
2,256 „ ...	Plastering with cement, ½" thick.
2,898 „ ...	Painting woodwork, 2 coats.
No. 16 ...	Removable chopping blocks.
200 r. ft. ...	Constructing 6" drain, semi-oval in section as per plate 194.
	Contingencies at 5 per cent.
	Petty supervision at 2½ per cent.
	Total Rs...

Quantity.	Description of work.
	Fish stalls.
1,661 c. ft. ...	Earthwork, excavation.
1,509 „ ...	Filling in basement with clean sand.
242 „ ...	Concrete, broken brick in lime mortar.
1,837 „ ...	Brickwork in ordinary mortar.
5 06 „ ...	Cutstone work.
211·17 „ ...	Teakwood, wrought and put up.
217 lbs. ...	Wrought-iron work.
2,380 sq. ft. ...	Roofing with Mangalore tiles over flat tiles including teak reepers, &c., complete.
931 „ ...	F[illegible] Cuddapah [illegible] pointed with [illegible] the slab.
2,314 „ ...	[illegible]
2,898 „ ...	[illegible] aint, 2 coats.
200 r. ft. ...	[illegible] oval drain as in [illegible]
	[illegible] at 5 per cent.
	[illegible] supervision at 2½ per cent.
	Total Rs...

BUILDINGS: MAIN DETAILS OF CONSTRUCTION OF DHOBIKHANAS AS GAINED FROM A STUDY OF PLANS.

A Dhobikhana: Plates 127 And 128.

In the above plates are illustrated the plan of a dhobikhana designed by Mr. W. Hutton, Sanitary Engineer to the Government of Madras, for certain Local Bodies in the Presidency of Madras. His specification report accompanying this design was as follows: 1. This is a complete and a feasible scheme to accommodate 48 dhobies and comprises one central well, pumping arrangements, platforms, cisterns, taps, rooms for ironing, ovens, stores, etc., and drainage system. 2. Each dhoby will use about 250 gallons of water per day of 10 hours. Therefore 48 dhobies will require (48 × 250) 12,000 gallons of water each day. The soil is presumed to be sandy at the site of the proposed dhobikhana and the subsoil water level is generally 2′ to 3′ below ground during monsoons and falls down to 8′ or 10′ during summer. Therefore a central well 6′ in diameter and 16 feet below ground level with four small radiating galleries 50′ long of 4″ open jointed stoneware pipes will be quite sufficient to meet the demands of a dhobikhana for 48 dhobies as it is expected to yield not less than 60 gallons per minute with a depression of 4 feet. However, a well 8′ in diameter, is provided in order to allow sufficient space for fitting up and working 2 pumps. 3. A cast iron tank with internal dimensions of 16′ × 16′ × 4′ and capacity of 6,400 gallons will be fitted up over the well on pillars built of laterite in lime and supported by girders as shown in plate 128. This tank is considered sufficient as it will hold more than the supply required for a half-day or 5 hours. It will be filled with water by hand-power lift and force pumps of the well known kite motion railway pattern. These pumps will be of the K pattern double barrelled brass pumps of 4″ bore and 2½″ suction and delivery pipes capable of pumping 1,500 gallons per hour. One pump will be sufficient to meet the demands of the dhobies. Therefore the second pump will be kept in reserve for use during repairs. 4. There will be 4 washing platforms capable of accommodating comfortably 12 dhobies in each. Each dhoby is provided with a fixed masonry cistern, a half-inch tap and laterite washing stone. The washing stone will not be fixed in masonry, as the dhobies generally adjust their positions and heights to suit their individual habits. 5. Four masonry platforms required, for starching, with rooms and tables for ironing at ends and 4 sets of sheds containing 12 rooms in each for country ovens, drains and drainage pits for sullage water, store rooms along the compound wall for keeping dirty and clean clothes and other stores, are provided. 6. The probable cost of the dhobikhana will be Rs. 43,000 and the Local Body may construct the well, washing platforms, the drains and drainage pits at once and gradually add up the platforms and rooms referred to above when funds are available.

Abstract Of Quantities For A Dhobikhana: Plates 127 And 128.

Quantity.		Description of work.
		General abstract.
		4 blocks of rooms for ironing, starching and drying clothes, during rains.
		4 blocks, each of 12 units, with country ovens, etc.
		4 washing platforms, each to accommodate 12 dhobies.
		Well, 8 feet in diameter.
		Iron tank house.
		4 radiating galleries.
		8 blocks, each of 6 units (store rooms).
		Compound wall.
		2 open drains.
		Pumps and pipes.
		Petty supervision at 5 per cent.
		Tools and plant at 2½ per cent.
		Contingencies at 5 per cent.
		Total Rs...
		Rooms for ironing, starching and drying clothes, during rains.
680 c. ft.	...	Excavating foundations.
408 "	...	Concrete, broken stone in chunam.
306 "	...	Laterite masonry in chunam.
71 sq. ft.	...	Pointing with chunam.
960 "	...	Flooring with 2″ Cuddapah slab on 4″ of concrete and neatly pointed with cement to the full depth of the slab.
1,400 "	...	Roofing with corrugated iron sheets including washers, bolts, nuts, etc., complete.
717 "	...	Walling with corrugated iron sheets including bolts, washers, nuts, etc., complete.
No. 1	...	Door with corrugated iron shutters, teak frames, hinges, bolts, etc., complete (2′ 6″ × 6′ 0″).
No. 4	...	Windows with corrugated iron shutters, teak frames, hinges, bolts, iron bars, etc.; complete (2′ 6″ × 4′ 0″).

Quantity.	Description of work.
No 5 ...	Ironing tables, wooden (3' 0"×6' 0").
7·5 c. ft. ...	Granite stonework.
133·02 " ...	Teak timber, wrought and put up.
386 lbs. ...	Iron work.
1,498 sq. ft. ...	Painting woodwork.
	Total cost of 1 block of ironing, starching and drying rooms.
	Total cost of 4 blocks of ironing, starching and drying rooms.
	Rooms with country ovens (1 block of 12 rooms).
640 c. ft. ...	Earthwork, excavating foundations.
384 " ...	Concrete, broken stone in chunam.
288 " ...	Laterite masonry in chunam.
67 sq. ft. ...	Pointing with chunam.
768 " ...	Flooring with 2" Cuddapah slab on 4" concrete and neatly pointed with cement to the full depth of the slab.
1,500 " ...	Roofing with corrugated iron sheets including washers, bolts, nuts, etc., complete.
2,494 " ...	Walling with corrugated iron sheets including bolts, washers, nuts, etc., complete.
No. 12 ...	Doors with corrugated iron shutters, teak frames, hinges, bolts, locks, keys, etc., complete (2'-6"×6'-0").
No. 12 ...	Country ovens.
10·5 c. ft. ...	Granite stonework.
123·76 " ...	Teak timber, wrought and put up.
1645 sq. ft. ...	Painting woodwork.
	Total cost of 1 block of 12 units for country oven.
	Total cost of 4 blocks, each of 12 units, for country oven.
	Washing platform.
476 c. ft. ...	Earthwork, excavating foundations.
575 " ...	Laterite masonry in chunam.
180 " ...	Laterite masonry in cement.
252 sq. ft. ...	Plastering with cement, ½" thick.
598 " ...	Pointing with chunam.
792 " ...	Flooring with 2" Cuddapah slab on 4" of concrete and neatly pointed with cement to the full depth of the slab.
12 No. ...	Washing stones.
	Total cost of 1 platform for 12 dhobies.
	Total cost of 4 platforms, each for 12 dhobies.
	Well, 8 feet diameter.
1,103 c. ft. ...	Earthwork, excavation.
710 " ...	Earthfilling.
612 " ...	Laterite masonry in cement.
1014 sq. ft. ...	Pointing with cement.
12 r. ft. ...	Well sinking (well, 8' internal diameter).
No. 1 ...	Wooden well curb, 8' internal diameter.
312 cwt. ...	Rolled bearer of British standard section including hoisting.
	Total cost of well.
	Iron tank house.
196 c. ft. ...	Concrete, broken stone in chunam.
188 " ...	Laterite masonry in chunam.

Quantity.	Description of work.
360 sq. ft. ...	Pointing with chunam.
9 c. ft. ...	Granite stonework.
12·86 cwt. ...	Rolled steel bearers of British standard section including hoisting.
No. 1 ...	Cast iron tank 16'-0"×16'-0"×4'-0" with a capacity of 6,400 gallons, etc., complete.
No. 1 ...	Fixing do.
	Total cost of iron tank house. ...
	Radiating galleries.
16,150 c. ft. ...	Earthwork, excavation.
400 " ...	Filling in with broken stones.
12,350 " ...	Filling in with clean river sand.
3,400 " ...	Filling in with excavated earth.
50 r. ft. ...	4" stoneware pipes with open joints including laying, etc., complete.
	Pumping charges.
	Total cost of 1 radiating gallery.
	Total cost of 4 radiating galleries, each 50 feet long.
	Store rooms (1 block of 6 units).
330 c. ft. ...	Earthwork, excavation.
198 " ...	Concrete, broken stone in chunam.
149 " ...	Laterite masonry in chunam.
35 sq. ft. ...	Pointing with chunam.
480 " ...	Flooring with 2" Cuddapah slab on 4" concrete and neatly pointed with cement to the full depth of the slab.
900 " ...	Roofing with corrugated iron sheets including bolts, etc., complete.
1,149 " ...	Walling with corrugated iron sheets including bolts, washers, nuts, etc., complete.
6 No. ...	Doors with corrugated iron shutters, teak frames, hinges, bolts, locks, keys, etc., complete (2'-6"×6'-0").
3·5 c. ft. ...	Granite stones.
66·39 " ...	Teak timber, wrought and put up.
943 sq. ft. ...	Painting woodwork.
	Total cost of store rooms, 1 block of 6 units.
	Total cost of store rooms, 8 blocks of 6 units.
	Compound wall, 10 feet long.
50 c. ft. ...	Earthwork, excavation.
20 " ...	Concrete, broken stone in chunam.
77 " ...	Laterite masonry in chunam.
140 sq. ft. ...	Pointing with chunam.
	Cost of compound wall, 10 feet long.
	Cost of compound wall, 950 feet long.
	Add cost of gate.
	Total Rs...
	Sludge pits.
181 c. ft. ...	Earthwork, excavation.
66 " ...	Laterite masonry in chunam.
131 sq. ft. ...	Plastering with cement, ½" thick.
32 c. ft. ...	Filling in with broken stones.
32 " ...	Filling in with gravel.

Quantity.	Description of work.
64 c. ft. ...	Filling in with sand.
	Total cost of 1 sludge pit.
	Total cost of 2 sludge pits.
	Open drain.
1,516 r. ft. ...	6″ open drain.
	Total cost of open drain.
	Pumps and pipes.
No. 2 ...	Hand power lift and force pumps of kite motion railway pattern with suction, delivery pipes, etc., complete.
No. 2 ...	Fixing power lift and force pumps of kite motion railway pattern with suction, delivery pipes, etc., complete.
2·80 tons. ...	Cast iron pipes.
6·64 cwt. ...	Cast iron specials.
500 r. ft. ...	Laying 2½″ pipes including excavation.
No. 66 ...	Cement joints.
No. 16 ...	Lead joints.
No. 48 ...	½″ water taps including wrought iron tubes, reducing elbows, etc., complete including fixing.
	Tota Rs...

BUILDINGS: MAIN DETAILS OF CONSTRUCTION OF CONSERVANCY DEPOTS AS GAINED FROM A STUDY OF PLANS.

Conservancy Depot: Plates 129 To 135.

In the above plates is illustrated the type design No. 156 issued with proceedings of the Madras Sanitary Board No. 476-S., dated 19-5-1914. The specification report which accompanied this design was as follows: The design was specially prepared for the Kumbakonam Municipality, but it is proposed to issue it as a type design as it can be adopted in other towns with such modifications as local conditions necessitate. The design for a conservancy depot comprises, (1) a bullock shed to accommodate 52 bullocks, (2) a contagious diseases shed to accommodate 8 bullocks, (3) an office and store room, (4) a smithy, (5) rubbish and sewage and night-soil cart-stands, (6) cattle attendants' quarters, (7) water supply arrangements, (8) drainage and (9) compound wall. The provision made in the design for contagious disease shed, office and store room, smithy, cattle attendants' quarters, etc., may be omitted at the option of the Local Body concerned. The design is intended merely as a model to be followed by any Local Body which wishes to build a conservancy depot; Local Bodies are not prohibited from providing more economical arrangements than those laid down in the design if they wish. Arrangement of buildings: The site plan in plate 129 shows the location of the different buildings enumerated above. Materials and principles of construction: General: Masonry: The structures are designed for brick masonry, but any local building material may be employed. But in such case the thickness of the walls should be suitably altered. Foundations: The foundations provided in the design are the minimum required in hard soil. They should be altered to suit the nature of soil at site. Roofing timber: Any of the timbers mentioned in the Chief Engineer's Circular, No. 2040-C, dated 29th April 1909, as applicable to Table I of Circular No. 234-C, dated 9th January 1908, may be used. Doors and windows: All doors and windows should be of teak. Painting: All wood-work and iron-work should be painted with three coats of silicate paint of chocolate colour and of an approved make: (1) Bullock shed to accommodate 52 bullocks, vide plates 133 and 134: This shed measures 150'×33' and is open at the sides. The two ends are closed by a masonry wall pierced with an opening in the centre 8 feet wide and 9 feet high. The shed is roofed with Mangalore tiles on teak reepers and teakwood rafters and purlins. The roof is supported by R.S. columns braced laterally by rolled steel joists. The basement will be 1 foot above ground level. The entrance to the shed for the bullocks in front and rear will be by a gravel ramp, as shown in the design. Flooring is of 4" cutstone with rough dressed surface on 4" surkhi concrete and the joints neatly pointed with cement. 12"×12" stone flagging may be used if procurable locally at a cheaper rate. They should be laid and jointed as above. Two feeding troughs will be constructed with 3" split granite slabs with a space of 4 feet between them as shown in the design, to serve as gangway for attendants. Rectangular drains, one on each side, constructed with cutstones will be provided to receive urine and washings. This form of drain is adopted in preference to semi-oval shape so as to prevent bulls accidentally getting their legs caught in a narrow deep drain. The drain will be sloped from the centre towards the end and will discharge into a cesspit provided at both ends. (2) Contagious diseases shed, vide plate 134: This shed is 30'×33' and will accommodate 8 bullocks. The details regarding its construction are the same as those of the main bullock shed. (3) An office and store room, vide plate 135: General: The design comprises (1) a watchman's shed, 10'×12', (2) office room, 20'×12', (3) medicine room, 15'×12', (4) store room 30'×12', (5) tools room, 30'×12' and (6) a verandah, 6 feet wide, in front. Cutstone work: Bed stones 9"×9"×6" are provided for verandah posts. Flooring will be of Cuddapah slab, $1\frac{1}{2}$" thick, on 4" concrete and the joints neatly pointed with cement to the full depth of the slab. Doors will be teak batten doors. The doors will have no sill pieces. The door posts will be tenoned into the Cuddapah slab floor. Windows will be batten with bars. Roof will be of Mangalore tiles over teak reepers. Finishing: The interior and exterior of walls will be plastered with chunam, two coats. (4) Smithy, vide plate 131: General: The smithy is 20'×10' with a hearth measuring 4'×4' as shown in the design. The whole structure is of iron with corrugated iron walls and roofing. The iron columns will be bedded in concrete. Flooring will be of 6" gravel, well rammed and consolidated. The forge will consist of a brick in clay hearth fitted with bellows of the pattern shown in the design. A wrought-iron dome and a wrought-iron chimney will be provided over the hearth as

shown in the design. If preferred, the forge may be placed in an open shed, only a portion of the shed being enclosed for keeping tools and materials, in which case the dome and chimney may be dispensed with. (5) Rubbish sewage and night-soil cart-stands, vide plate 135: A platform measuring $320' \times 20'$ is provided for rubbish carts and another $150' \times 20'$ for night-soil and sewage carts. The floor of the cart-stands will be formed of 6" gravel, well rammed, with ramps all round as shown in the design. It is not considered necessary to provide sheds for carts. They will be better out in the open. As a protection against sun, sheds are not required as the carts will be in the depot only during the nights. Exposure to rain will not do them any harm, but will help to keep them clean. If there is no municipal workshop, a shed will be necessary for repairing the carts. In this case special arrangements will have to be made in the depot, and the smithy and workshop may be combined together. (6) Cattle attendants' quarters, vide plate 132: (7) Water-supply, vide plates 129 and 130: The provision consists of a well, pump shed, reservoir with distribution pipe and fountains. Well: The well is 10 feet in diameter and will be sunk or built to suit local conditions. It should be at least 10 feet below summer water level. The steining below the summer water level will be built in brick in clay and above that with brick in chunam. The parapet will be 7 feet high to prevent people from drawing water from it by dipping vessels. The space between the excavation and sides of the steining below summer water level will be filled in with clean gravel or broken stone and above that with clay puddle as shown in the design. The parapet and steining inside up to summer water level will be plastered with cement, $\frac{1}{2}''$ thick. (If stone masonry is used for steining it may be pointed with cement.) Step irons should be provided for access into the well and for repairing the suction pipe, etc., when necessary. The pump shed will be an open shed, $10' \times 10'$, roofed with Mangalore tiles on teak reepers and rafters as detailed in the design. A kite motion, railway pattern, double brass barrel pump with $3\frac{1}{2}''$ diameter barrel and $2\frac{1}{2}''$ suction and delivery, capable of delivering 1,000 gallons per hour, is provided. The horizontal length of suction pipe from well to the pump will be laid with a gentle rise as shown in the design. Reservoir: The reservoir will be a wrought-iron tank $10' \times 10' \times 5'$, thickness of plate being 3/16", and capable of holding 2,800 gallons with a depth of $4\frac{1}{2}'$ of water. The tank will be roofed with 22 B.W.G. corrugated iron sheets over teakwood rafters, etc. The gables will be closed with expanded metal fixed in teak frames. The tank will rest on four rolled steel girders $7'' \times 4'' \times 16$ lbs. carried on two double-headed iron rails fixed to the heads of the posts. The posts will be of double-headed iron rails braced diagonally by iron $3'' \times 3'' \times \frac{1}{4}''$. Distribution pipes and fountains, etc.: The distribution will consist of 3" cast-iron pipes, fountains, hydrants, etc., as indicated in the plan, plate 129. Watering trough, vide plate 131: Three watering troughs with a platform all round and a splash wall on both sides have been provided. The troughs will be filled from the reservoir by a 3" main and taps. The splash wall provided will be $7\frac{3}{4}$ feet high and will prevent the splashing of water outside when the animals are washed. The flooring of the platform will be of cutstone with rough surface laid on 6" concrete and neatly pointed with cement. (8) Drainage: Open drains will be constructed to carry the washings and sullage of the different sheds. The sewage from the depot will be discharged into existing sewage drains or disposed of in an adjoining farm if land is available or treated biologically and the effluent discharged into an adjoining ditch. Open drains will be semi-oval in section as in plate 194. (9) Compound walls with gates, plate 129: There will be a compound wall of brickwork in mud, plastered with two coats of chunam. As an alternative, any form of unclimbable wire fence or steel paling may be provided. The body of the wall will be of brick in mud. There will be a coping of brickwork in chunam as shown in the design. Wooden gates, 12 feet wide, with gate pillars are provided. (10) Fencing hay stacks: Either iron wire or other fencing should be provided around the hay stacks.

Abstract Of Quantities For A Conservancy Depot: Plates 129 To 135.

Quantity.	Description of work.
	General abstract.
	Bullock sheds.
	Contagious disease shed.
	Office and store room.
	Smith's shed.
	Rubbish and night-soil and sewage cart-stands.
	Cattle attendants' quarters.
	Water-supply.
	Drainage.
	Compound wall.
	Fencing the hay stacks.
	Conserving the tank.
	Tools and plant at $2\frac{1}{2}$ per cent.
	Contingencies at 5 per cent.
	Petty supervision at $2\frac{1}{2}$ per cent.
	Total Rs. ...

Abstract Of Quantities For A Bullock Shed For 52 Bullocks: Plates 133 And 134.

Quantity.	Description of work.
1,834 c. ft. ...	Excavating foundations.
931 „ ...	Concrete in lime mortar.
1,581 „ ...	Concrete in surkhi mortar.
1,638 „ ...	Brick in lime mortar.
36 „ ...	Archwork.
1,803 „ ...	Cutstone work.
1,479 sq. ft. ...	Plastering with chunam, two coats.
1,479 „ ...	Whitewashing, two coats.
5,123 „ ...	Pointing with cement.
77 „ ...	Plastering with cement.
11·125 tons. ...	Rolled steel girders.
18·866 cwt. ...	Wrought-iron work.
537 c. ft. ...	Teakwood, wrought and put up.
469 sq. ft. ...	Teakwood louver.
No. 4 ...	Teakwood finials.
6,383 sq. ft. ...	Roofing with Mangalore tiles on teak reepers.
10,451 „ ...	Painting, chocolate, two coats.
750 c. ft. ...	Gravelling.
No. 52 ...	Providing rings to tie up bulls.
	Contingencies.
	Total Rs. ...

Abstract Of Quantities For A Contagious Disease Shed: Plate

Quantity.	Description of work.
1,005 c. ft. ...	Excavating foundations.
426 „ ...	Concrete in lime mortar.
324 „ ...	Concrete in surkhi mortar.
1,012 „ ...	Brick in lime mortar.
36 „ ...	Archwork.
374 „ ...	Cutstone work.
1,479 sq. ft. ...	Plastering with chunam, two coats.
1,479 „ ...	Whitewashing, two coats.
1,003 „ ...	Pointing with cement.
24 „ ...	Plastering with cement.
32·16 cwts. ...	Rolled steel girders.
287 lbs. ...	Wrought-iron work.
94·71 c. ft. ...	Teakwood, wrought and put up.
70 sq. ft. ...	Teakwood louver.
No. 4.	Teakwood finials.
1,360 sq. ft. ...	Roofing with Mangalore tiles on teak reepers with flat tiles.
1,741 „ ...	Painting with chocolate, two coats.
150 c. ft. ...	Gravelling.

Abstract Of Quantities For An Office And Store Shed: Plate 135.

Quantity.	Description of work.
2,159 c. ft.	Earthwork, excavation and filling in.
2,572 „	Filling in basement.
565 „	Concrete in lime mortar.
5,435 „	Brick in lime mortar.
126 c. ft.	Archwork.
6,457 sq. ft.	Plastering with chunam, two coats.
4 c. ft.	Cutstone work.
1,713 sq. ft.	Flooring with $1\frac{1}{2}''$ Cuddapah slab on 4″ concrete.
188 „	Flooring with $1\frac{1}{2}''$ Cuddapah slab only.
178 c. ft.	Teakwood, wrought and put up.
6,457 sq. ft.	Whitewashing, two coats.
3,068 „	Roofing with Mangalore tiles on teak reepers.
130 „	Teakwood battened doors with frames, etc., complete.
240 „	Teak battened windows with iron bars, etc., complete.
3,076 „	Painting, two coats, with chocolate paint.
	Total Rs. ...

Abstract Of Quantities For A Smith's Shed: Plate 131.

Quantity.	Description of work.
133 c. ft.	Excavating foundation and filling in.
93 „	Concrete, broken bricks in lime mortar.
7·95 cwt.	Rolled steel girders.
19 „	Wrought-iron work.
52 c. ft.	Brick in lime mortar.
64 sq. ft.	Plastering with chunam, two coats.
1,225 „	Corrugated iron, 24 B.W.G.
108 „	Corrugated iron, 24 B.W.G. doors and windows with angle iron, hinges, rivets etc., complete.
372 „	Painting, chocolate, two coats.
76 „	Painting, coal tar, two coats.
158 c. ft.	Gravelling.
No. 1	Bellows with lever, etc., complete for working.
	Total Rs. ...

Abstract Of Quantities For Rubbish And Sewage Cart-Stands: Plate 135.

Quantity.	Description of work.
5,485 c. ft. ...	Gravelling.
	Total Rs. ...

Abstract Of Quantities For Huts For Cattle Attendants: One Block Of 4 Huts: Plate 132.

Quantity.	Description of work.
1,270 c. ft. ...	Earthwork, excavation for foundations.
301 „ ...	Filling in basement with earth.
1,407 „ ...	Country brick in lime mortar (foundation and basement).
1,166 „ ...	Country brick in mud (superstructure).

Quantity.		Description of work.
454 c. ft.	...	Country brick in lime mortar (superstructure).
70 „	...	Archwork, country brick in lime mortar.
66·56 „	...	Country wood, wrought and put up.
156 sq. ft.	...	Country wood, batten doors with frames, iron fittings, complete.
80 „	...	Country wood, batten windows with frames, iron fittings, complete.
701 „	...	Flooring with 6″ square tiles over 4″ concrete and pointing with cement.
44 „	...	Flooring with Cuddapah slabs over 4″ concrete.
268 „	...	Gravelling, 6″ thick, well watered and rammed.
1,256 „	...	Roofing with Mangalore tiles on flat tiles including reepers, etc., complete.
192 „	...	Roofing with Mangalore tiles including reepers, etc., complete.
4,129 „	...	Plastering with lime mortar, one coat.
1,435 „	...	Tarring, two coats.
66 „	...	Honeycomb tile work.
55 r. ft.	...	6″ masonry drain including concrete filling and cement plastering, etc., complete.
Lump sum.		Forming fire places in kitchen.
		Total Rs. ...

Abstract Of Quantities For Water Supply Of A Conservancy Depot: Plates 129, 130 And 131.

Quantity.		Description of work.
		Well, pump shed and reservoir.
3,247 c. ft.	...	Excavating foundations for well, 1st footing.
3,386 „	...	Do. 2nd do.
2,230 „	...	Do. 3rd do.
1,485 „	...	Do. 4th do.
300 „	...	Excavating foundations.
260 „	...	Concrete in lime mortar.
2,527 „	...	Broken stone filling.
2,233 „	...	Clay puddling.
2,918 „	...	Earth filling.
840 „	...	Brick in clay.
899 „	...	Brick in lime mortar.
890 sq. ft.	...	Plastering with cement, two coats.
114 „	..	Plastering with cement, ½″ thick.
144 r. ft.	...	Double-headed iron rails.
5·71 cwt.	...	Rolled steel girders.
4·21 „	...	Wrought-iron work.
120 sq. ft.	...	Expanded metal, ⅛″ size.
182 „	...	Corrugated iron, 24 B.W.G.
30·75 c. ft.	...	Teakwood, wrought and put up.
No. 8.		Teakwood finials.
144 sq. ft.	...	Roofing with Mangalore tiles on teak battens.
No. 15.		Wrought iron steps for well.
1,262 sq. ft.	...	Painting, chocolate, two coats.
Lump sum.		Pump, brass, railway pattern, double-barrelled, including fixing, etc., complete.

Quantity.		Description of work.
Lump sum.		Cast iron tank, 10′ × 10′ × 5′ with hoisting, fixing, etc.
		Supply and delivery.
118 cwt.	...	Supply and delivery of 3″ cast iron pipes.
38 „	..	„ of 2½″ cast iron pipes.
13·77″	...	Bends, branches, collars, etc.
17·016″	...	Flanged pipes and bends.
No. 1	...	2½″ foot valve with strainer.
150 r. ft.	...	2″ wrought-iron tubes, galvanised.
No. 1	...	2″ do. bend, galvanized.
„ 1	...	2″ × 1¼″ reducing coupling.
„ 2	...	2″ × 1¼″ tees.
„ 6	...	1¼″ elbows.
„ 3	...	1¼″ × ¾″ reducing couplings.
30 r. ft.	...	1¼″ wrought iron tubes.
No. 6	...	Fire hydrants.
„ 9	...	Hydrants with stand posts.
„ 2	...	Single-tap fountains.
„ 3	...	3″ sluice valves.
„ 1	...	2″ stop cocks.
„ 2	...	2½″ sluice valves.
„ 3	...	½″ taps.
„ 6	...	Surface boxes for hydrants.
„ 5	...	Do. for sluice valves.
„ 1	...	Do. for stop cocks.
		Laying and jointing.
12,882 c. ft.	...	Earthwork, excavation.
1,000 ft.	...	Laying 3″ cast iron pipes.
No. 158	...	Jointing 3″ cast iron pipes.
325 r. ft.	...	Laying 2½″ cast iron pipes.
No. 76	...	Jointing 2½″ cast iron pipes.
153 l. ft.	...	Laying and jointing 2″ wrought iron tubes.
40 „	...	„ 1¼″ wrought iron tubes.
No. 15	...	Fixing hydrants.
„ 3	...	Do. 3″ sluice valves.
„ 2	...	Do. 2½″ sluice valves.
„ 2	...	Erecting fountains.
		Watering troughs.
1,972 c. ft.	...	Excavating foundations.
542 „	...	Concrete in lime mortar.
713 „	...	Do. surkhi mortar.
1,491 „	...	Brick in lime mortar.
661 „	...	Cutstone work.
2,934 sq. ft.	...	Plastering with chunam, two coats.
745 „	...	Plastering with cement, ½ inch thick, two coats.
1,321 „	...	Pointing with cement.
		Total Rs. ...

Abstract of Quantities For Open Drains For A Conservancy Depot: Plate 129.

Quantity.		Description of work.
		For 6″ open drain.
753 c. ft.	...	Earthwork.
300 "	...	Concrete, brick jelly in mortar.
215 "	...	Brick in mortar.
170 "	...	Brick on edge.
365 sq. ft.	...	Plastering with cement, ¾″ thick.
425 "	...	Pointing with cement.
		Add extra 6″ drain for six branches.

Quantity.		Description of work.
		For 9″ open drain.
2,100 c. ft.	...	Earthwork.
702 "	...	Concrete, brick jelly in mortar.
773 "	...	Brick in mortar.
342 "	...	Brick on edge.
1,103 sq. ft	...	Plastering with cement, ¾″ thick.
885 "	...	Pointing with cement.
No. 2	...	Cesspools.
" 1	...	Catch pit or cistern.
" 1	...	Collecting well to sewage farm.
		Total Rs. ...

BUILDINGS: OPENING UP OF CONGESTED AREAS: PLANNING OF VILLAGE AND TOWN EXTENSIONS: THE DESCRIPTION OF SOILS AND STRATA BEST SUITED FOR THE ERECTION OF BUILDINGS IN RESPECT TO STABILITY AND HEALTHINESS OF THE DWELLINGS ERECTED THEREON.

Introduction.

There is no doubt that at the present day considerable interest is being evinced in Town-planning schemes by all Government and Local Bodies throughout the world. Whether the methods adopted for securing proper town-planning schemes by the authorities are on sound principles is rather a doubtful question. When Government introduced this subject in the revised syllabus in advanced Minor Sanitary Engineering, I do not think Government intended that your knowledge in this part of the subject should be so specialised as to qualify you for being appointed as assistants to Town-planning experts. It is the opinion of Professor Geddes that there is no such thing as a town-planning expert and that any body could town-plan, and that the most they could in their age was to try and recover in some way the use of this great lost art. However, in the matter of the objects of town-planning the opinion of this expert is as follows: The problem of town-planning was so to design as to give individuality and variety to buildings, and not to perpetuate monotony, as in the case of the dreary and regular buildings of the bye-law plan. People, he believed, would be unfit for social, military, educational and intellectual services in increasing numbers in the monotonous dreariness of life if there were no individuality and variety. He could not imagine that a healthy and vigorous population could be produced in numbered rows of buildings. They should differentiate and individualise their neighbourhood as completely as possible. They should think out detail after detail of each of those things. Healthy town-planning was a definite culture of life, in which they were trying to grow human beings more and more effectively, and the business of town-planning was essentially to render homes more and more effective. In these days of new streets and new improvements they were largely repeating the errors of Europe in the generations before the last. He exhorted them to preserve the hereditary homes of poorer citizens and the keeping of all *pucca* houses and the sweeping away of *kutcha* ones, thus incurring the minimum of compensation to those who were displaced. Town-planning may, therefore, be defined as the art of planning towns in respect of the distribution of buildings and open spaces and provision of streets and roads suitable to each area. In all cases of town-planning the first requisite is a public authority possessed of power to control, guide and regulate the growth and development of towns, especially as regards building sites, their approaches and surroundings. Such powers generally include the prevention of the growth of ugly suburbs and mean streets or lanes and securing for the inhabitants of any particular locality a sufficient supply of the essentials of a healthy life: namely, sunlight, fresh air, and vegetation. I do not propose to deal exhaustively with this subject and I will therefore refer you to the following list of literature on this subject. Books: (1) "Town-Planning in Practice" by Raymond Unwin, 21 s. net. (Publisher T. Fisher Unwin). (2) "The Garden City" by C. B. Purdom, 10*s.* 6*d.* net. (Publishers J. M. Dent & Sons, Limited). (3) "Practical Housing" by J. S. Nettlefold, popular edition, 1*s.* 6*d.* (Publisher T. Fisher Unwin). (4) "Town-Planning and Modern Architecture" at the Hampstead Garden Suburb, 2*s.* 6*d.* (Publisher T. Fisher Unwin). (5) "A Study in City Development" by Professor Geddes. (6) "Notes on Housing Question," including the case against Municipal House Building. Reprinted from the *Birmingham Daily Mail.* E. C. Osborne and Son, Borough Press, Birmingham. Price 1*d.* (7) Extracts from Evidence given before the Glasgow Municipal Commission on the Housing of the Poor, 1903. (8) "A Housing Policy." Cornish Bros., Ltd., 37, New Street, Birmingham. Price 6*d.* (9) Birmingham Housing Committee's Reports. (i) Information on general Housing Conditions and their causes. Chairman's speech explaining recommendations, October 20th 1913. (ii) Property imperfectly repaired, February 6th 1906. (iii) Town-Planning, July 3rd 1906. And Chairman's speech in support of it. (10) Lantern Lecture, explaining the Birmingham Housing Committee's Slum Reform work, and advocating Town-Planning. Delivered in the Birmingham Town Hall, March 28th 1906. (11) "Midland Conference on Town-Planning," October 27th 1906. (12) "Slum Reform

and Town-Planning." Birmingham and District Housing Reform and Open Spaces Association, 293 A, Broad Street, Birmingham. (A leaflet.) (13) "Housing Problem—Present powers of Local Authorities." Reprinted from the *Local Government Officer*, October 5th, 1907. (A leaflet.) Association of Municipal Corporations: (i) Minutes of Council Meeting, June 13th, 1907. (ii) Deputation to Premier, August 7th, 1907. (14) "Town-Planning in Theory and Practice." Garden City Association. Price 1s. (15) Itinerary, for visitors coming to inspect Birmingham's Slum Reform work.(16) "Town-Planning at Harborne." Reprinted from the *Birmingham Gazette and Express*. September 21st, 1907. (A leaflet). (17) "Co-partnership Housing by the Workers, for the Workers." Reprinted from the *Birmingham Gazette and Express*. September 8th, 1908. (A leaflet.) (18) "Plan of an Ideal Town." By Dr. Ludwig Hercher of Wiesbaden. (19) "Houses and Homes." Reprinted from the *Sphere*. May 23rd 1908. (20) "Harborne Tenants Ltd." Descriptive pamphlets, 1908 and 1909. (21) "Ancient Town-Planning" by F. Haverfield. Net. 6s. Clarendon Press. (22) Town-Planning, with special reference to the Birmingham schemes. By George Cadbury, Junior. Messrs. Longmans, Green and Company, 7s. 6*d*. net. (23) Town Planning Institute Transactions. (24) Practical Town-Planning by J. S. Nettlefold, 2s. net. (25) A Practical Guide in the preparation of Town-Planning schemes by E. G. Bentley and S. Pointon Taylor, 5s. net. Periodicals: (1) "Town-Planning Review." Quarterly, 10s. 6*d*. per annum. (2) "Garden Cities and Town-Planning." Monthly, 4s. per annum. (3)"The American City." Monthly, 8s. 4*d*. per annum. (The above three may be obtained from the Garden Cities and Town-Planning Association, 3, Gray's Inn Place, London, W. C.). (4) "The Municipal Journal." Weekly 8s. per annum (The Municipal Journal, 80, Fleet Street, London, E. C.). (5) "The Local Government Review." 12s. per annum (The Cavendish Press, 25, White Press, Moor Lane, London E. C.). (6) Co-Partnership. A monthly journal published by Co-partnership Tenants, Ltd., 6, Bloomsbury Square, London, W. C. Price 1*d*.

Primary Objects Of Town Planning.

In the admirably popular book 'Practical Housing' by J. S. Nettlefold, the primary objects of Town Planning are thus summarised: "1. To facilitate and encourage thorough *co-operation* between all concerned in the provision and supervision of housing accommodation for the people, in order to provide town populations with the light, air, and space essential to human health. Such co-operation would avoid the waste now caused by inelastic bye-laws, which give Local Authorities no power to meet landowners in the cost of estate development, even when they are willing to restrict the number of houses per acre, and provide open spaces for rest and recreation. Town extension is a business question, and should be dealt with on give-and-take business lines. Red tape is fatal. 2. To ensure the exercise of *foresight* in reserving plenty of room where eventually main thoroughfares will be required. During the last thirty years a vast expenditure has fallen on the ratepayers of England for the demolition of buildings which never ought to have been put up. 3. To take into account *everything* that helps to make life worth living, to consider the surroundings of a house as well as the house itself. Cheerful surroundings are quite as important as healthy homes. Town Planning may be considered as an endeavour to do for a town what an architect does for a house, when he sits down to draw out the plans before digging his foundations. He considers what he wants, and then does his best to fit in his various requirements to a harmonious whole. It is only by this means that he obtains what is required at a reasonable cost. The wise development of a town is of vital importance, not merely to one individual, but to a very large number of people, and the questions to be considered are much more numerous and complicated than the questions involved in the erection of a single house. If it is necessary (and everyone recognises that it is) to plan out a house as a whole before starting to build, then a thousand times more it is necessary in the interest of public health, public convenience, and public economy, to plan out towns as a whole before new developments are allowed. The first principle of Town Planning is to consider beforehand the constituent parts of a modern town, and then to arrange them in such a way that the result shall show an ordered harmony. We cannot suddenly undo all the mistakes of the past, but at least we can try to prevent mistakes in the future by planning out in a comprehensive manner urban and suburban districts before the work of development is commenced. If we had power to consider first how existing towns ought to have been planned, and then year by year to make our town improvements in accordance with that plan, we might by degrees correct past mistakes, and on systematic economical lines gradually bring our centres of population up to the standard required by modern conditions of life. Instead of that we remedy a bit here and a bit there, in the piecemeal and extravagant fashion now accepted as satisfactory by people generally who do not know how much better things could be managed, and in fact are managed elsewhere. The principle of Town Planning has proved of great assistance in other countries in the co-ordination of town improvements, and could be

used in a similar direction here also. But there is a much larger possibility of usefulness in the planning out beforehand of new districts. It is so much easier, as well as so much cheaper, to prevent evils than to undo them. The constituent parts of a town may be roughly divided under the following heads: 1. Manufactories. 2. Warehouses. 3. Offices. 4. Shops. 5. Public parks, playgrounds, and small spaces. 6. Public buildings. 7. Private dwelling houses. 8. Public streets and other means of communication. A town extension plan contemplates and provides for the development as a whole of every urban, suburban, and rural area likely to be built upon during the next thirty or fifty years. Wide avenues are provided for the main traffic between the centres and the outskirts, narrower streets for ordinary traffic, and again narrower and less expensive roads or drives for purely residential quarters. Parks and small open spaces and playgrounds are provided for beforehand, instead of waiting till the land required has risen to an impossible price, and in a sensible plan these "lungs" are located on back land, not on valuable frontage, as is so often the case to-day in this country. Districts are allocated for factories on the opposite side of the town to that from which the prevailing winds come, and here there are railway lines, and, where possible, water communications. The future town is divided into districts, and these districts are graded. High buildings close to each other are allowed in the centre and on the main arteries; in residential districts buildings must be lower and more dispersed the further they are from the centre of the city or its main arteries. In those streets where traffic is light, and a sufficient distance is maintained between the opposite lines of houses, narrow and inexpensive roadways or drives are allowed in order to keep down the cost of estate development, which in modern English suburbs is responsible for at least 1*s.* per week on a 6*s.* 6*d.* house. Warehouses should be placed in a convenient position for the factories and other consumers of the goods stored there. Business offices should be in the centre of the town, where land is dear, because the heavy ground rent is more than met by the time and money saved by the convenience of this position. Public buildings should also, as far as is convenient for the work they have to do, be placed in the centre of the town in commanding positions, not only for the sake of the time and money saved by the convenience of the position, but also as a reminder of the town's corporate existence, and a daily inspiration to local patriotism. The natural position for shops is on the main thoroughfares, where customers are continually passing to and fro. The shop-keepers will have heavier rents and rates to pay in main thoroughfares than in side streets, but their position acts as an advertisement, and they will make more money with which to meet their increased liabilities. This question as to how far shop-keepers benefit from wide streets is a controversial point. It is obvious that if there were two main thoroughfares running parallel to each other, the one wide and the other narrow, more people would use the wider street, assuming, as we must, that both streets provided an equally short route between different parts of the town. On the other hand, experienced shop-keepers in Bond Street, London, contend that they get more trade in a narrow street where customers can, from either footpath, see the goods displayed in any given shop. It is quite possible that the people who use Bond Street spend more money per head than the people who use Regent Street, but I venture to think that the total business done in a given length of Bond Street shopping, is very much less than in the same length of equally well-managed Regent Street shopping, because in the latter street so many more people are able to pass backwards and forwards. If this view is correct, then shop-keepers, as well as other business men, can afford to pay in their ground rents a great part, if not all the cost of the wide main avenues necessary for through traffic. Public parks, playgrounds, and open spaces, on the other hand, should, as far as possible, be situated on cheap land—what is technically known as back land. It is a lamentable waste of money to use up valuable frontage with a park, which would be far more pleasant and healthful for those who frequent it, if placed as far possible from the noise and bustle of the town. These places are required for rest and recreation, and therefore it is more efficient, as well as more economical, to put them in side streets or at the backs of houses. This is specially important in the case of play-grounds for little children. A mother of the poorer classes has no time to take her babies to the park; they have to fend for themselves, and cannot go more than a very short distance from home, nor is it safe for them to cross main thoroughfares. One of the first essentials to an efficient town plan is to have dotted about at very frequent intervals, on cheap land, small plots of open ground, where the little ones can amuse themselves without being a nuisance to others, or in danger themselves, as they now are when playing in the streets. The same principle applies with equal force to the situation of the houses themselves. Under present arrangements, a considerable item in the rent of small houses is the ground rent for the land on which they and their back yards stand, and this is due to the fact that poor men live on dear land, whereas rich men live on cheap land. The time has come for recognising this unfortunate anomaly, and redressing it to the utmost of the power of those

responsible for the management of national and local affairs. Landowners who at first opposed Town Planning are now, with very few exceptions, strong supporters of the policy, and frequently assist in drawing out the plans. They find in the long run that Town Planning *pays them*, besides benefiting the community. Illustrations must assist written explanations, and I am much indebted to Dr. Ludwig Hercher for permission to reproduce his ideal town plan. This is an imaginary plan (plate 136) arranged to provide for all the requirements of town work and town life in a complete, harmonious, and economical manner. Wide tree-planted avenues are provided for the convenience of main traffic, and here are located the shops and business premises of those whose commercial enterprises will be greatly benefited by the position of their establishments. Narrower streets for ordinary traffic, and again narrower and less expensive roads or drives for purely the residential quarters of the poorer as well as of the richer classes, so that the weekly rents of small houses may not be artificially forced up by the interest on the money spent on road making, where a narrower roadway with trees and grass on either side would be all sufficient for the traffic, and infinitely healthier and pleasanter for the residents.

Parks and small open spaces and playgrounds are provided for beforehand, instead of waiting till the land required has risen to an impossible price, and these lungs are located on back land, not on valuable frontage."

Widths Of Streets.

The maximum width usually provided under existing bye-laws is 50, 42, 40 or even 36 feet. The town-planning experts recommend a width of 72 feet. In a road of 50 feet width, the usual practice is to make the carriage-way 26 feet and the two foot paths 8 feet, the total width of the road between the building lines being 50 feet, *vide* fig. in plate 139. In the case of the town-planning road which is generally 72 feet wide the carriage-way is made 16 feet, the two foot paths on both sides of the carriage-way are separated by turfs 5 feet wide. The foot paths themselves are each 8 feet wide. The remaining space of 30 feet is used as two front gardens, each of a width of 15 feet, *vide* fig. in plate 139.

Houses To The Acre.

The English bye-laws allow 56 houses to the acre. Some experts say that the number should not exceed 12 and they further add that this number should be economically feasible. The arrangement of 56 houses to the acre under the bye-laws is illustrated in plate 137. Professor Geddes in one of his lectures on town-planning apportioned the areas for roads, houses, gardens, factories and parks as under: Roads 12 per cent., houses 6·6 per cent., gardens 64·8 per cent., factories 6·6 per cent, parks, etc., 10 per cent. This is of course a theoretical distribution.

Examples Of Lay-Out.

The usual lay-out of a parachery in the city of Madras before the town had the privilege of hearing Professor Geddes and Mr. Lanchester is illustrated in plate 147. The plan of house grouping method recommended by Professor Geddes is illustrated in plate 139. This method is open to varied requirements and possesses the advantage that each group or row may be treated individually. In this method, of course, roadways become considerably economised and gardens enlarged accordingly. A typical plan of a lay-out as given in the book "Practical Housing" by J. S. Nettlefold is illustrated in plate 138. In plate 140 is illustrated the plan of a lay-out of a new extension in a town in the Presidency of Madras as proposed by Professor Geddes. In plates 141 and 142 are given two diagrams, one showing an extension with the usual conservancy lanes as first proposed by a Local Body which was estimated to cost Rs. 23,500; and the other diagram illustrates the same proposal as amended by Professor Geddes which was estimated to cost Rs. 14,250. In another case in which the Local Bodies proposed to lay out three new straight roads by acquiring houses in a built-up area, *vide* plate 143, at a cost of Rs. 30,000, Professor Geddes suggested the re-alignment of the roads in such a manner as will necessitate the pulling down of only kutcha houses, *vide* plate 145, with the result that this area when opened up as suggested by Professor Geddes would result in its being as shown in plate 144. The cost of the revised proposals of Professor Geddes was estimated at Rs. 5,000. In plate 146 is illustrated the lay-out of an extension (a) as first proposed by a Local Body, (b) as subsequently revised by a Local Body and (c) as finally revised by Professor Geddes. The different stages of the improvements effected at each revision are shown below:

Particulars of the extension as first proposed by the Local Body.

Length of Roads	...	3285′ (×45′)	4635′
Do. Lanes	...	1350′ (×13′)	
House Sites ...	...	51	
All 51 Plots ...	...	45′×60	
Houses and Gardens	...	3·16 Acres	
Public Gardens ..	...	Nil	
Roads and Lanes	...	3·79 Acres	

Particulars of extension as revised by the Local Body.

Length of Roads	...	2240' (×40')
Do. Lanes	...	Nil
House Sites	...	59
Houses and Gardens	...	5 Acres
2 Public Gardens	...	0·8 Acres
Roads and Lanes	...	2·07 Acres

Particulars of extension as finally revised by Professor Geddes.

Length of Roads	...	2100' (×40')
Do. Lanes	...	70' (×10')
House Sites	...	56 or 55
28 Small Plots	...	45'×60'+
22 Large Plots (Average)	...	50'×75'+
5 Larger Plots Do.	...	55'×110'+
Houses and Gardens	..	5·12 Acres
2 Public Gardens	...	1·26 Acres
Roads and Lanes	...	3·65 Acres
Temple or Hall	...	1

Soils And Strata.

Generally speaking, soils are classified under (1) surface soil and (2) sub-soil. Of the latter, there is usually an intermediate layer between the surface soil and the hard underlying stratum below. From the character of moisture tenacity, the soils are classified as (1) pervious soils and (2) impervious soils; the former class is more or less porous to water and allows it to pass through, while an impervious soil allows no water or practically none to penetrate its surface. The usual descriptions of the different soils are (1) common earth, (2) clay, (3) sand, (4) gravel, (5) disintegrated soft rock and (6) rock. In the above category of soils, I have excluded 'made soil' as this is not a natural soil but is the product of sweepings and dry rubbish of all kinds. From a health point of view, rocks, gravel and sand are suitable soils for building on. Earth and clay are generally unhealthy.

Sites For Healthy Dwellings.

The question of site for a dwelling house, in most instances, is not one of selection on sanitary grounds. From a sanitary point of view, the site for a dwelling should possess the following characteristics: 1. The site should be free from surface contamination. 2. The surface should have a natural slope to permit of easy drainage. 3. The soil at site should not be damp and tenacious of moisture. 4. The sub-soil water should be as low as possible and at a constant level. 5. The site should not be low-lying compared with its surroundings. The ground air is impure due to the gaseous products of decomposition of organic and inorganic constituents of the soil. The quantity of ground air depends upon the character of soil. Hard rocks contain little or none while porous soils contain from 30 per cent. to 70 per cent. of air. An impermeable basement for houses is a necessity as it prevents the ground air from rising within houses. The ground air is in continual movement brought about by changes of temperature, by rainfall and by wind pressure. In a site where the level of sub-soil water fluctuates greatly, air is displaced when water rises in the soil and is sucked in when the sub-soil water falls. The ground air is saturated with watery vapour in damp soils. Dampness of soil is one of the chief causes for a number of diseases such as phthisis, rheumatism and malarial fevers. The amount and moisture of ground air are influenced by sub-soil water. When it is near the ground the site is damp. When the sub-soil water level falls, outside air enters the moist ground favouring decomposition. A site where the sub-soil water does not rise to more than 15 feet below the surface should be preferred. Sites in which the sub-soil water rises to about 5 feet below the surface should be condemned. The measures adopted to keep the sub-soil water at a constant level will be described later on.

Healthy And Unhealthy Construction.

The essential points of healthy construction are: (*a*) A site which is clean and dry. (*b*) Efficient protection from the admission of air and moisture from the sub-soil into the house. (*c*) Walls and roofs which will effectually keep out wet, and to some extent be proof against fluctuations of heat and cold. (*d*) Materials sound in quality and free from organic impurities. (*e*) Rooms of sufficient size for habitation, properly lighted and provided with suitable means of ventilation. The principal sources of unhealthiness in dwellings are: Building on made ground, wet sub-soil, damp walls, rotten floors, dead vermin, defective drains, low ceilings and small windows, polluted water supply, foul cisterns, and non-removal of house refuse. Unhealthy situations are, generally speaking, those which are lowlying especially if on marshy ground or if surrounded by large trees. Some situations are rendered unhealthy although not naturally so, by the construction of cemeteries, refuse destructors, burrow pits, etc. Unhealthy soils are clay, peat and made earth, especially if the ground water level is near the surface. Some are only indirectly unhealthy like chalk which makes the water "hard.' Sand and gravel are generally good, but if sub-soil water is within 5 feet of the surface, the site will be unhealthy. Precautions to be adopted are: Build on high ground and if not on top of hill; divert water from higher ground away from site; drain off sub-soil water; remove large trees from immediate vicinity; provide proper ventilation and effective water supply and drainage; build damp-proof course

in walls; avoid locations for accumulation of filth and dirt; provide a suitable impermeable floor consisting of at least 6 inches of concrete plastered with cement.

A Cheap Dwelling House.

In plate 9 is illustrated the type design No. 109 issued with proceedings of the Madras Sanitary Board, No. 24/S, dated 26th January 1911. The specification report which accompanied this design was as follows: Estimated cost from Rs. 240 to Rs. 380. General: Each house shall measure 40 feet in length and 20 feet in breadth inclusive of walls. The disposition of rooms, doors and windows shall be as shown in the design. 2. Foundations will be 3 feet deep in the case of the central wall and 2 feet in all other cases. The whole of the foundations will be built with sun-dried brick in clay. If random rubble in clay is cheaper than brickwork the foundations may be built of the former. 3. Basement will be 18″ high at front and 9″ high in the rear of sun-dried brick in clay as shown. In places where stonework is cheaper than brickwork the basement may be built of the former. 4. The filling in of the basement shall be with well rammed earth. 5. Superstructure will be of sun-dried brickwork in clay. In places where stone is cheaper than brick the walls may be built of the former. 6 Flooring will be 3″ concrete well rammed and plastered over with cement in the case of kitchen, latrine and washing platform. The other rooms shall be floored with clay and cowdung coating after well ramming the filling in the basement. 7. Plastering will be with clay and cowdung coatings and when thoroughly dry shall receive two coats of whitewash which should be renewed every year. 8. Roofing will consist of pan tiles laid over bamboo rafters, reepers and matting over ridge piece and wall plates. 9. Doors and windows will be batten and braced of the cheapest wood such as Karumarudu. All parts of woodwork which come in contact with the walls shall be well tarred just before erection. 10. Drainage: The surface water in the open yard will be carried by an earth drain as shown in plan to the main open drain in the conservancy lane. The drains from the latrine, washing platform and kitchen shall be of brick in chunam plastered with cement and shall connect to the open drains in the conservancy lane the junctions being slightly curved in direction of flow as shown on the plan.

Abstract Of Quantities For A Cheap Dwelling House: Plate 9.

Quantity.	Description of work.
1,354 c ft. ...	Earthwork excavation.
851 " ...	Filling in basement with earth.
4,104 " ...	Sun-dried bricks in mud.
3,816 sq. ft. ...	Plastering with clay and cowdung coating.
3,816 " ...	Whitewashing.
619 " ...	Flooring with clay and cowdung coating well rammed complete.
171 " ..	Flooring with 3″ concrete well rammed and plastered over with cement.
1,541 " ...	Roofing with bamboo rafters, matting and reepers including pan tiles complete.
22 c. ft. ...	Country woodwork wrought and put up.
272 sq. ft. ...	Doors with country wood shutters including fittings complete.
52 " ...	Windows with country wood frames, batten shutters including fittings and fastenings complete.
	Forming ditch drain, and drains in latrine and washing platform, etc., complete.
	Sundries.
	Total per block.
	Total per house.

Compound Walls.

In plate 96 is illustrated the design for a dwarf compound wall. In plates 97 and 98 is illustrated the type design No. 89 for compound walls in different materials issued with proceedings of the Madras Sanitary Board, No. 145-S., dated 1st May, 1901. No specification report accompanied this design. The different classes of materials adopted for the compound walls shown in these two plates will be found detailed in the abstract of quantities.

Abstract Of Quantities For Compound Walls: Plates 97 And 98.

Quantity.	Description of work.
	Design No. 1 *(a)*.
30 c. ft. ...	Excavation.
2 " ...	Filling in with earth.
23 " ...	Concrete in chunam.
46 " ...	Brick in mud.
5 " ...	Brick in chunam.
1·06 sqrs. ...	Plastering with chunam
...	Contingencies.
	Design No. 1 *(b)*.
30 c. ft. ...	Excavation.
3 " ...	Filling in with earth.
23 " ...	Concrete in chunam.
46 " ...	Brickwork in chunam.
1·06 sqrs. ...	Plastering with chunam.
...	Contingencies.

Quantity.	Description of work.
	Design No. 2 (*a*).
40 c. ft. ...	Earthwork excavation.
3 „ ...	Filling in with earth.
33 „ ...	Concrete in chunam.
68 „ ...	Rough stone in mud.
10 „ ...	Rough stone in chunam.
·95 sqrs. ...	Pointing with chunam.
·23 „ ...	Plastering with chunam.
...	Contingencies.
	Design No. 2 (*b*).
40 c. ft. ...	Excavation.
3 „ ...	Filling in with earth.
38 „ ...	Rough stone in chunam.
60 „ ...	Rough stone in mud.
3 „ ...	Concrete in chunam.
20 sq. ft. ...	Slab stone (1½″ thick).
1·02 sqrs. ...	Pointing with chunam.
...	Contingencies.
	Design No. 3.
40 c. ft. ...	Excavation.
3 „ ...	Filling in with earth.
30 „ ...	Concrete in chunam.
50 „ ...	Laterite stone in chunam.
·86 sqrs. ...	Pointing with chunam.
...	Contingencies.

Quantity.	Description of work.
	Design No. 4 (*a*).
20 c. ft. ...	Excavation.
95 „ ...	Mud walling.
·75 sqrs. ...	Whitewashing over mud plaster.
·30 „ ...	Coping with country tiles bedded in chunam.
...	Contingencies.
	Design No. 4 (*b*).
20 c. ft. ...	Excavation.
95 „ ...	Mud walling.
·75 sqrs. ...	Whitewashing over mud plaster.
20 r. ft. ...	Coping with Mangalore tiles bedded in chunam.
10 „ ...	Ridge tiles.
...	Contingencies.
	Gate with Pillars.
24 c. ft. ...	Excavation.
2 „ ...	Filling in with earth.
19 „ ...	Concrete in chunam.
38 „ ...	Brick in chunam.
·91 sqrs. ...	Plastering with cement including cornice.
2·4 c. ft. ...	Teakwood, wrought and put up.
19·6 lb. ...	Iron work.
1 No. ...	Hinge at top of frame with bolt and eye piece complete.
1 „ ...	Iron pin at bottom of frame for moving gate with ring for post.
1¾ c. ft. ...	Cutstone work.
...	Contingencies.

BUILDINGS: DETAILS OF NIGHTSOIL DEPOTS AND A KNOWLEDGE OF METHOD OF TRENCHING, COVERING, ETC.

Ideal Conditions.

In this Presidency, the excreta collected in carts from public and private latrines are usually conveyed to a plot of land and there buried in trenches. The site where the night-soil is buried is called a 'Night-Soil Depot' or a 'Trenching Ground.' The method of disposal of excreta in this manner is called 'trenching.' In the first place, it would be as well that we understand the rationale of this system of disposal of excreta from a town population. The primary object is to convert the stuff as far as possible as manure or fit food for plants. The complex nitrogenous organic matter of the night-soil is converted into simple nitrates when buried in soil by the action of a class of bacteria which are found in the soil and known as nitrifying bacteria. This process is effectual only when oxygen is plentiful and this is so in the upper layers of the soil. The conditions favourable for trenching are: 1. The soil should be light, fertile, sandy, loam. 2. The dimensions of trench should be 20′×18″×12.″ 3. The depth of night soil dumped into the trench should be 3″. 4. The remaining depth of 9″ of the trench should be filled with earth removed from the trench after being broken up as finely as possible. 5. The space between each trench from centre to centre should be four feet six inches. 6. The filled-in trenches should be left undisturbed for a minimum period of 18 months. 7. On the assumption that all the above conditions are complied with, the area of trenching ground to be provided should be on a rate of 1 acre for every 250 people. As it is impossible to obtain the ideal conditions described above, the usual procedure may now be described.

Usual Practice.

The ground is arranged as shown in fig. 1, plate 222. The depth of the trenches should not be less than 12″ and not more than 18″. In some places it has been the practice to make the depth of the trench as little as 6″ with the object of keeping the night-soil as near the surface as possible. Theoretically, this method is very good but in practice it will be found that by the action of the hot Indian sun and high winds, there is sure to be caused a very infective dust from such grounds; another disadvantage in shallow trenching is that a large number of trenches will be required. The length of the trench should be 20′ to 30′ and longer lengths than this are not recommended for the reason that difficulty will be felt in filling the trenches. The space between trenches should be as a minimum two feet. The usual depth to which the trench should be filled with night-soil may be taken as $\frac{1}{4}$ or $\frac{1}{3}$ of the total depth. As regards breadth, the usual breadth is 18″. The filling of the trench with night-soil is done only to $\frac{1}{4}$ or $\frac{1}{3}$ of the depth of the trench. The trench should be filled up with earth such that the night-soil is being broken up as fine as possible by the operation of filling and that there is sufficient depth of covering of earth soil so that there is no nuisance by the night-soil coming up to the surface as night-soil swells up usually. A minimum depth of 9″ of sand is necessary for covering the night-soil. For a minimum distance of 2 furlongs there should be no dwelling houses, $\frac{1}{2}$ a mile is much better. The trenching ground should be located as far as possible away from the prevailing winds. The surface flow from such trenching grounds should be carefully treated on land and every endeavour should be made to avoid the storm water drainage passing into running streams or rivers. No trenching ground should be placed near the banks of streams. A tope of bamboo trees or such other rapid growing trees or mango trees intervening the trenching ground and the town would be very advantageous. A light fertile sandy loam is the best. Pure sandy soil is the next best. Black cotton soil is good for trenching as long as the soil is dry and when wet it becomes a sticky mud. Stiff clay is most unsuitable. Black cotton soil is good for this reason as the night-soil is rapidly deodorised by the easily powdered and very absorbent dry black cotton soil. The usual area to be provided for a trenching ground is the area required for a population for a period of 3 years without using any part of the land twice in the period. A trenching ground therefore should be of this area as a minimum. The quantity of excreta from an Indian town population has been found by experiments in Madras to be ·013 cubic foot. Cabbages, turnips, tobacco sometimes, are cultivated and Bengal jute also. In a trenching ground a well is to be dug for the purpose of washing the buckets, carts, etc., and also for irrigation purposes. The method of working the trenches is to keep plenty of new trenches in hand sufficient for 3 days' use; for it is usual with these trench diggers to be absent without notice because of a religious festival when these men do not work but are also

usually drunk. The man in charge of these trenches should see that as soon as the carts discharge their load of night-soil in the trenches the excreta is covered up with earth. The primary object of trenching excreta is frustrated if the trenches filled in with night-soil are left exposed for a large number of hours without being filled in with earth. Everything which causes delay to the cartmen on the trenching ground should be seen to and avoided; *e.g.*, night-soil carts should be made to tip their contents into separate trenches so that one cart does not interfere with the working of another cart but permits of the filling in of the several trenches at the same time.

WATER SUPPLY: INTRODUCTION.

Past Progress in Madras Presidency.

I cannot do better than quote the following extracts from a paper read by Mr. Hutton before the 1911 'All-India Sanitary Conference' at Bombay: "The number of inhabitants in the Madras Presidency, according to the latest census taken in 1911, is given as 41,401,839. This number may for all practical purposes be divided into three principal parts or divisions: The North-east or Telugu part, population 16,000,000. The South or Tamil part, population 21,000,000, and The West or Malayalam and Canarese part, population 4,000,000. Of these three divisions the most progressive in the way of sanitary reform and in the provision of water supply and drainage works is the South or Tamil followed by the Telugu-speaking part in the north-east. The West or Malayalam and Canarese part is at present backward in the advancement of sanitary measures, the apparent reason being the heavy annual rainfall which ensures generally sufficient water supply from wells while at the same time the road-side drains, backyards, and streets are periodically flushed and cleansed. The area of the Presidency is given as 1,41,705 square miles of which 78,000 square miles may be allotted to the North-east or Telugu part, 53,000 square miles to the South or Tamil part and 10,000 square miles West or Malayalam and Canarese part. The number of municipalities in the Presidency is 61 excluding the Corporation of Madras and in addition there is a large number of unions or large villages subordinated to the Taluk and District Boards. These unions, with the help of the District Boards, are now coming forward with requests for water supply and drainage works thus following the example of the municipalities. Proposals for drawing up water supply and drainage schemes are usually first suggested by the Sanitary Commissioner during his inspection of towns, and occasionally by the Sanitary Engineer or the Local Bodies themselves. Owing to the progress made in educating the Local Bodies to the necessity for water supply and drainage works and to encouragement given to such proposals by the last two Governors of Madras, Lord Ampthill and Sir Arthur Lawley, and also to the generous financial assistance offered by the Madras Government the number of such proposals has steadily increased until the Sanitary Engineer has now 53 schemes on his programme to be investigated and drawn up in detail as soon as possible. The increase in the number of water supply and drainage proposals has rendered necessary an increase in the Sanitary Engineer's staff which now consists of myself, four Assistant Sanitary Engineers, one personal assistant, twelve surveyors and twenty-seven members of the drawing office. The investigation and drawing up of schemes for water supply and drainage works is solely undertaken in the Madras Presidency by the Sanitary Engineer with the exception of those for the City of Madras which Corporation maintains its own engineering staff. The introduction of water supply and drainage works in the Presidency outside the City of Madras may be said to have started with the appointment of a Sanitary Engineer to Government in January 1890. The first progress made was in the introduction of the earlier water supply works. Drainage works were not carried out at first, the Sanitary Engineer's time and funds available being concentrated on the provision of water supplies. It was found that Municipal Councils were unable to arrange for the introduction of both water supply and drainage works and consequently the latter works were deferred and the old earthen side drains and badly laid masonry ones were called on to serve the impossible duty of dealing with the spill water from public fountains and the increased sullage discharge from house drains due to the augmented supply brought by the water mains and house connections. The result was stagnation of sullage water in these drains and encouragement to the propagation of mosquitoes. Various attempts were made to deal with the spill water from fountains and lately the provision of filter trenches of special design and what is called filter wells have been stated by one Council to have satisfactorily disposed of the nuisance. Plans of these filter trenches and filter wells are shown in plates 179 and 180. Despite the disadvantage due to difficulties in disposal of, or want of disposal of increased quantities of sullage, there is no intention to defer the introduction of piped water supplies in mufassal towns where the introduction of a drainage work simultaneously is still financially impossible. It is considered that the resulting improvement in health to the inhabitants of a town by the introduction of a protected and pipe water supply far outweighs the disadvantages resulting therefrom by the absence of efficient drainage arrangements. Thanks mainly to the high average temperature and the absence of rain for the greater part of a year, the soil at the roadside drains is more porous than it would otherwise be and the makeshift arrangements for disposal of spill water at fountains and the provision of

cesspools, more or less impervious, for house sullage, minimise the evil results from the absence of good drains. In the Sanitary Commissioner's administration report, for 1910 the health statistics amongst others, of 12 towns possessing protected water supplies were given and Government in reviewing this report remarked as follows: "The bearing which water supply has on the prevalence of cholera is illustrated by the statistics embodied in statement XIII appended to the Sanitary Commissioner's report, from which it appears that, in the twelve towns where an improved system of water supply has been in force for more than five years, the average mortality from this cause was 5'8 per cent. of the total mortality during the quinquennium ending with 1910 as against 19'8 per cent. for the five years immediately preceding the date of the introduction. It may be added that under fevers there was a simultaneous and not less marked improvement from 25 to 16'5 per cent." As none of these towns possess modern drainage works the gain to the health of a town by the provision of a protected water supply scheme, even when unaccompanied by a drainage scheme, is considerable and this fact should be remembered by those who think that, because a town cannot afford to construct simultaneously both water supply and drainage works, the former should not be introduced in advance of the latter. It may be taken as the accepted policy in the Madras Presidency that the provision of a piped water supply in mufassal towns is approved prior to the introduction of a drainage scheme. While the necessity for the provision of a drainage scheme is recognised this drainage scheme is deferred owing solely to the want of funds. It seems to me that, with funds limited, the provision of a piped water supply is of first importance. Local supplies from wells, tanks and rivers in the vicinity of towns are without exception contaminated and the consumption of water from contaminated areas affects more directly and quickly the health of the people, than the stagnation of sullage however bad it may be. Under the Madras District Municipalities Act, the maximum tax that can be enforced for water supply and drainage purpose, is 8 per cent. The income of an ordinary mufassal municipality of 30,000 inhabitants in the Madras Presidency from this 8 per cent. tax can be taken as Rs. 14,000 to Rs. 15,000 which represents an available provision of capital if borrowed at 4 per cent. repayable in 30 years, of 2½ lakhs of rupees. Assuming for simplicity that the working expenses of a suitable water supply scheme are paid from the general revenues of the municipality this sum of 2½ lakhs is all that is available from municipal funds for the provision of water supply and drainage works. As the cost of a water supply scheme, involving pumping by suitable pumping plant, may be taken as from 3 to 4 lakhs of rupees for an average municipality of 30,000 inhabitants it will be noticed that without assistance from outside sources such a municipality is unable to carry out either water supply or drainage schemes and certainly not both. Owing to the generous encouragement and financial assistance of Government and in certain cases of private individuals, notably the Maharanee Appalakonda Yamba of Vizianagram, the Mahant of Tirupati and the Hon'ble Mr. S. R. M. Ramaswami Chettiar of Chidambaram, a fair number of towns in the Madras Presidency now possess piped water supplies. Certain of these towns owing to rising revenue, an increasing interest in sanitary matters, and the desire to construct drains and thus remove the nuisance caused by the additional discharge of sullage into earthen side drains or cesspools, have now resolved to construct drainage works on modern lines. The number of water supply schemes carried out in mufassal towns in the last 21 years in the Madras Presidency, practically since the appointment of a Sanitary Engineer was sanctioned, is 25 excluding the City of Madras. A list of these schemes is given below."

Number.	Name of town.	Population when scheme was drawn up.	Population for which the scheme was designed.	Number of gallons and supply for which works were designed. Total.	Per head.	Actual or estimated cost.	Cost per head. Population in col. 3.	Population in col. 4.	Average maintenance cost.	Average cost of maintenance per head. Population in col. 3.	Population in col. 4.	Remarks.
1	2	3	4	5	6	7	8	9	10	11	12	13
						RS.						
1	Adoni	26,212	30,000	300,000	10	1,57,319	6	5·2	3,908	·19	·13	Gravitation: Storage tank, filter beds and service reservoir.
2	Bezwada	24,224	40,000	600,000	15	3,11,790	12·9	7·8	9,207	·40	·23	Pumping: Wells and service reservoir.
3	Coconada	40,685	50,000	750,000	15	5,02,342	12·4	10·5	13,100	·32	·26	Pumping: Storage tank and filter beds.
4	Conjeevaram ...	42,561	56,000	840,000	15	2,69,231	6·3	4·8	16,363	·38	·29	Pumping: Infiltration gallery and service reservoir.
5	Coonoor (Hill station).	6,049	7,500	150,000	20	1,85,394	30·6	24·7	3,470	·57	·46	Gravitation: Impounding reservoir and service reservoir.
6	Cuddapah	18,982	20,000	200,000	10	1,17,615	6·2	5·8	4,297	·22	·21	Pumping: Gallery and service reservoir.
7	Dindigul	16,000	22,000	220,000	10	1,30,150	8·2	6·0	3,603	·22	·16	Gravitation and pumping: Gallery and service reservoir.
8	Gudiyattam ...	21,335	25,000	150,000	6	81,000	3·8	3·3	1,868	·08	·07	Pumping: Infiltration gallery and service reservoir.
9	Guntur	30,833	30,000	450,000	15	2,55,471	8·3	8·5	5,725	·18	·19	Gravitation: Springs and service reservoir.
10	Kurnool	24,523	30,000	450,000	15	2,63,667	10·75	8·8	12,957	·53	·43	Pumping: Canal, storage tank and service reservoir.
11	Madura	87,426	100,000	1,500,000	15	3,94,738	4·5	3·9	27,602	·32	·27	Pumping: Submerged filter bed.
12	Nellore	32,040	35,000	525,000	15	1,65,562	5·2	4·7	7,815	·25	·22	Pumping: Infiltration gallery and standpipe.
13	Ootacamund (Hill station).	10,000	20,000	400,000	20	5,75,836	57·5	28·8	7,519	·75	·37	Gravitation: Impounding reservoirs.
14	Salem	70,621	80,000	1,200,000	15	9,10,535	12·9	11·4				Gravitation: Storage tank and service reservoir.
15	Tanjore	54,055	60,000	900,000	15	4,47,420	8·3	7·4	27,788	·51	·46	Pumping: Submerged filter bed and service reservoir.
16	Tirupati	14,242	24,000	360,000	15	2,31,000	16·2	9·6	2,489	·17	·10	Gravitation: Gallery and service reservoir.
17	Trichinopoly ...	88,715	88,000	1,320,000	15	7,68,251	8·7	8·7	41,586	·47	·47	Pumping: Gallery and service reservoir.
18	Vellore	44,950	50,000	750,000	15	3,22,860	7·2	6·4	2,702	·06	·05	Gravitation: Impounding tank, filter beds and service reservoir.
19	Vizagapatam ...	34,487	40,000	600,000	15	4,71,804	13·7	11·3	11,959	·35	·30	Gravitation: Impounding reservoir, filter beds and service reservoir.
20	Berhampur	25,745	30,000	450,000	15	3,11,000	12·1	10·3	1,845	·07	·06	Gravitation: Storage tank, filter beds and service reservoir.
21	Chidambaram ...	19,909	30,000	450,000	15	3,97,650	20·0	13·3	12,814	·65	·43	Pumping: Channel, storage tank and service reservoir.

Number.	Name of town.	Population when scheme was drawn up.	Population for which the scheme was designed.	Number of gallons and supply for which works were designed. Total.	Per head	Actual or estimated cost.	Cost per head. Population in column 3.	Population in column 4.	Average maintenance cost.	Average cost of maintenance per head. Population in col. 3.	Population in col. 4.	Remarks.
1	2	3	4	5	6	7	8	9	10	11	12	13
						Rs.						
22	Periyakulam ...	17,960	24,000	36,000	15	1,62,670	9·1	6·8	1,500	·09	·06	Gravitation: Filter beds and service reservoir.
23	Vizianagram ...	37,270	50,000	750,000	15	4,26,790	13·1	9·7	13,586	·36	·27	Pumping: Infiltration gallery and service reservoir.
24	Kodaikanal (Hill) station.	1,912	3,500	70,000	20	82,700	43·2	23·6	1,400	·73	·40	Gravitation: Impounding reservoir.
25	Negapatam ...	57,190	82,250	1,236,750	15	7,46,760	13·0	9·1	14,538	·25	·18	Pumping: Infiltration gallery and service reservoir.

New Proposals.

Water is an article of first necessity to all of us. Without pure water, there cannot be health. The demand for water is (A) for the personal use of individuals for (1) cooking, (2) fluid drinks (water, coffee, tea, etc.), (3) ablution, (4) washing of utensils, (5) washing of house floors, (6) flushing latrines, (7) flushing house drains, (8) washing clothes; (B) for the use of the Local Bodies for (1) cleansing of the streets, (2) flushing drains and sewers, (3) flushing public latrines, slaughter houses, (4) public baths, (5) road forming, etc; (C) for the use of public institutions, such as Railway Stations, Hospitals, Schools, Colleges, Hostels, Dhobykhanas, etc.; (D) for manufacturing purposes; and (E) for construction of new houses and for repairs of old houses. The population of this Presidency as per 1911 census is distributed as follows: I. 3 Cities with a population of 100,000 and over, 7,72,309; II. 8 Cities with a population between 50,000 to 100,000, 4,80,385: III. 3 Municipalities and 6 Local Boards with a population of between 20,000 to 50,000; 1,208,099; IV. 14 Municipalities and 106 Local Boards with a population of between 10,000 and 20,000, 1,647,246; V. 4 Municipalities and 404 villages with a population of between 5,000 to 10,000, 2,680,722; VI. one Municipality and 3,717 villages with a population of between 2,000 to 5,000, 10,671,268; VII. 7,947 villages with a population of between 1,000 to 2,000, 11,087,248; VIII. 10,131 villages with a population of between 500 and 1,000, 7,285,082; IX. 31,741 villages with a population of under 500, 5,530,787; floating population, 42,264; total 41,405,404. The water supply of the City of Madras commands the services of specially trained and experienced Sanitary and Engineering authorities. In the case of the 61 Mufassal Municipal towns, 25 towns possess protected water supplies. The water supply of Mufassal towns has the first claim on the attention of the Sanitary and Engineering authorities. The introduction of public water supplies on approved sanitary principles is beset with (1) financial difficulties, (2) location and present condition of villages, (3) ignorance of sanitary principles and (4) want of matured proposals. Even assuming that well thought-out and matured proposals are available, the amount of funds required to carry out protective water works in this Presidency on a rough basis of Rs. 10 per head would be 4,140·5 lakhs; deduct amount already spent on water works, say, 140·5 lakhs; leaving 4,000 lakhs of Rupees as requirements for water works in this Presidency. The amount required, *viz.*, 4,000 lakhs, it will be admitted, cannot immediately be found. Even granting that the whole possible requirement of 4,000 lakhs for initial cost

is found, there is the further sum required to maintain the water works which may be taken as, say, 310 5 lakhs annually. From the above, it will at once be seen that we should improve our water supplies as funds become available. The benign Government gives large free grants year after year and loans to Local Bodies towards sanitary projects. The amounts thus made available supplemented with such small amounts as may be available in the financial resources of Local Bodies swell to a considerably large amount, say as much as 40 or 50 lakhs every year. As regards location and present condition of villages, the following extract from the 1911 Census report by Mr. J. Chartres Molony, I.C.S., will be found interesting. "The vast majority of the population enumerated live in villages; and the village of Southern India bears little resemblance to the mental picture suggested by the word in its European sense. 'Instead of orderly rows of fairly substantial houses fronting some well used thoroughfare, the incipient statistician finds a bewildering medley of cottages, leaf huts, cow-sheds and straw yards arranged on no apparent plan and often lying hidden in a grove or isolated in a swamp, miles distant from any public highway. At the first glance, it would seem well nigh impossible to account even for the villages of the Presidency, without seeking further to ascertain the number of houses in each such village, and that of the inhabitants in each house. The problem, however, becomes simplified by a consideration of already existing administrative divisions. The Presidency is divided into districts, each district into divisions, each division into taluks, each taluk into firkas. If a firka contains on an average some 25 to 30 villages, the formidable total resolves already into defined units of not unmanageable size. Further more, if he essays himself to draw up the house list of a village the bewildered Superintendent gathers comfort from a gradually observed fact. If to him the ordinary village is merely a planless maze of blind alleys and crooked lanes, to the Karnam, who has lived there all or most of his life, this tangled skein presents no particular difficulty. Whether he actually perambulates the village or casts up an account in the reflective ease of his verandah, it does not take him very long to set down the tale of houses and chief occupant of each." As regards the ignorance of the masses, it must be admitted that they are ignorant and you are expected to educate the masses in sanitary matters. As regards the want of matured proposals, the Government Sanitary Engineer and the local staff of Sanitary Inspectors and Overseers are the agencies to reduce this defect little by little. Schemes of water supply may be classed under two classes, *viz.*, (1) major schemes costing over Rs. 10,000, and (2) minor schemes costing Rs. 10,000 and below. The major water supply schemes have to be designed by the Government Sanitary Engineer. With the financial facilities most benevolently afforded by Government for Local Bodies year after year, considerable progress in improvements to water supply might be looked for. The want of well thought-out and matured proposals is the chief obstacle for progress in this direction. There is no doubt that this defect can be remedied to a large extent by the sanitary and engineering staff of Local Bodies. In the first place, I want to emphasise the fact that proposals for water supply should satisfy the following requirements: (1) evidences of the necessity for an improved water supply should be satisfactory, (2) efficiency from sanitary and engineering stand points should be reasonably expected, (3) avoidance of luxury and benefiting equally the rich and poor are necessary; and (4) proposals should be complete with regard to plans, estimates, specifications and report.

WATER SUPPLY: VARIOUS SCHEMES: GENERAL PRINCIPLES GOVERNING DESIGNS OF VARIOUS SCHEMES.

Pumping Installations For Village Water Supplies.

In plates 163 to 166 is illustrated the method which was adopted for supplying a portion of Salem with water from a small pumping installation and masonry cistern. The Government of Madras considered the works as suitable for small supplies and circulated the plans and estimates with report for information of Local Bodies. The installation is thus described in Mr. Hutton's report "The work comprises the following, (*a*) deepening the spring to a further depth of 5'89 feet in the Arisipaliem tank to afford an additional supply of water; (*b*) installing a 7½ B. H. P. Engine and 3" centrifugal pump with necessary suction and delivery pipes; (*c*) constructing an engine house; (*d*) constructing a masonry tank with 20 taps. A portion of the town of Salem depends for its supply of water on this tank and during the hot weather the water in the tank was available in small quantities and at a depth of some 27 feet below ground level. People drew their supply of water by entering into the water by a flight of 27 steps and of a vertical height of 27 feet and thus contaminated the small quantity of water available in the deep pits of the tank. In plate 163 is shown the position of the tank and the sites of the works executed. To prevent the inconvenience of the people descending and ascending a large number of steps and getting into the tank to withdraw their supply and thus contaminate the water in the tank, a service reservoir has been built above ground level into which the water is pumped by an oil engine and pump. The service reservoir has been fitted with 20 taps. In order to increase the yield from the pit in the tank, it has been deepened an additional depth of 5'89 feet (*vide* plate 164). It may here be stated that as at this depth the natural hard rock has been met with, there is no use in deepening it any further. The yield from this spring has been tested after deepening and found to be 34,650 gallons per day. If an additional supply of water is considered necessary then the pit for the whole area may also be deepened to the bottom level of the spring now deepened. But I think actual measurement of the quantity available shows that a proposal to supply 2 or 3 hundred thousand gallons to Salem from one well located at Salem is very considerably exaggerated. Plate 164 shows also the suction and delivery pipes as laid. The engine installed is a 7½ B. H. P. Hornsby's oil engine, this being the only size available and the pump erected is a Gwynne's 3" centrifugal pump. The installation has been tested and is found to fill the reservoir (capacity above draw-off level 5,775 gallons) in about 25 minutes or 5,775/25 or 231 gallons per minute. The minimum lift is 31 feet and the maximum is 40 feet. The plan of the engine house is shown in plate 165. The service reservoir shewn in plate 166 has a total capacity of 6,412 gallons and above draw-off level its capacity is 5,775 gallons. The reservoir is fitted with 20 taps. The reservoir has been built in Municipal land and there was therefore no necessity for acquiring any land for the purpose. The cost of the works as executed amounts to Rs. 5,000. As the spring had essentially to be deepened and as the plant and pipe fittings had to be purchased locally from immediately available stock and as the work had to be executed urgently to afford immediate relief the first estimate of the work has been exceeded by Rs. 1.400. The only requirement to complete the arrangement is the provision of a second pump with suction and delivery pipes. During the monsoon periods, the pump now erected will, it is expected, be submerged as M.W.L. of the tank is 77'92 and the platform level of the pump at present is 66'99. To enable this second pump being fitted at any time, the masonry of the pump has been raised to 6" above M.W.L. The cost of the second pump with suction and delivery pipes including erection will be Rs. 600. (This pump has since been erected). The annual cost of maintenance will be as follows: Bulk Russian oil for 7½ B.H.P. engine at one pint per B.H.P. per hour, for 4 hours daily pumping at As. 8 a gallon, $7\frac{1}{2} \times 4 \times \frac{1}{8} \times \frac{1}{2} \times 365$, Rs. 685; lubricating oil, waste and sundries, Rs. 60; one driver at Rs 12. Rs. 144; one cooly, at Rs. 5, Rs. 60; and repairs and sundries, Rs. 101; total Rs. 1,050. I take this opportunity of pointing out that for several years back, Colonel King has been recommending similar installation to avoid the pollution caused by the use of step wells. The present installation is believed to be the first one executed and other Municipalities might be disposed to go in for similar schemes on the experience of Salem."

Gudiyattam Water Works.

Gudiyattam is a town in the district of North Arcot with a population of 23, 390 (as per 1911

census). This town lies 3 miles north of the Palar and about the same distance from the Railway Station. It is divided into two main portions by the Koundinia river. Koundinia river is one of the various small rivers which rise in the Hills and flow southwards into the Palar. The town is now provided with a protected water supply comprising (1) an infiltration gallery, 200 feet long, constructed in the Koundinia river at a point about 3, 700 feet from the nearest point in the main portion of the town ; (2) a pump house located on the left bank of the river immediately adjoining the infiltration gallery and installed with two Hornsby's oil Engines and two Worthington Deane triple plunger double acting power pumps; (3) an 8" pumping main of cast iron 3, 700 feet long from the pumping station to the service reservoir; (4) an elevated masonry reservoir capable of holding one seventh of a day's supply and (5) distribution pipes, sluice valves and fountains. The scheme was designed by Mr. W. Hutton, Sanitary Engineer to the Government of Madras in August 1904, and sanctioned by Government in August 1905. The works were completed and brought into operation in 1908. Owing to the severity of cholera cases in the town, year after year, the need for a protected water-supply for this town was pointed out by the Sanitary Commissioner for Madras as early as 1895. Owing to want of funds and other causes, the scheme became an accomplished reality in 1908. The present supply is obtained from the underflow in the bed of the Koundinia river and is drawn from an infiltration gallery of the design shewn in plate 173. At the point selected for the gallery the river is 590 feet broad and the depth of sand in the bed of the river at this point is 19 feet. The population of Gudiyattam as per last censuses was as follows: 1871 census, 10,804; 1881 census, 10,641; 1891 census, 18,747; 1901 census, 21,335; 1911 census, 23,390. The scheme now in operation was designed for a population of 25,000. The rate of supply per head per day was taken at 6 gallons as this quantity was considered as the minimum likely to serve sanitary ends and the maximum that financial considerations permitted. The daily supply provided for in the scheme is therefore 25,000 × 6 or 1,50,000 gallons. The rate of draw-off for town consumption purposes was fixed at $\frac{1,50,000}{12 \times 60}$ or 209 gallons per minute. The town distribution pipes are calculated to be of sizes capable of supplying the daily quantity in 12 hours or one half the daily quantity in 6 hours. Pumping takes place only during 16 hours each day in two shifts of 8 hours each. The quantity raised by the pumping plant per minute is $\frac{1,50,000}{16 \times 60}$= 158 gallons. The length of the gallery is 200 feet long and consists of two rows of 6 inch stoneware pipes laid 8 feet below lowest summer water level. The gallery is of section shewn in plate 173. The water after passing through the gallery arrives at a collecting well. From the collecting well a 12" cast iron pipe, 10 feet long conveys the water to a suction well whence it is pumped into the elevated reservoir located in the town. The pump house is shewn in plate 173 and consists of masonry foundations and basement and corrugated iron superstructure and roof. There are two units at this station so that one unit will always be in reserve. Each unit is designed for the work as under: Maximum water-level in elevated reservoir, 66·25, *vide* plate 176; lowest draw-off level at suction well, *vide* plate 173, 21·32; static head = 44·93; frictional head required in 8" pumping main, 3,700 feet long with gradient $\frac{11}{10000} = 4·07$; total lift for pumps = 49 feet; gallons to be raised per minute as stated above = 158. Pump horse power = $\frac{158 \times 10 \times 49}{33000} = 2·4$ P.H.P. Taking efficiency as, say, 45 per cent. B.H.P. = $\frac{2·4 \times 100}{45} = 5·4$, add 20 per cent. for slip of belt, etc. = 1·1; total B. H. P. = 6·5. Two Hornsby oil engines of $6\frac{1}{2}$ B. H. P. each with two Worthington Deane triple plunger double acting power pumps are provided. One set of engine and pump is always in reserve. The pumping main from the pumping station to the service reservoir is 3,700 feet long. It is 8 inches in diameter and discharges the required quantity of 158 gallons per minute with a hydraulic gradient of 11 in 10,000. The site of the reservoir is shewn in plate 174. The reservoir design is shown in plates 175, 176 and 177. It is an elevated tank built of masonry. It is capable of holding 21,328 gallons or $\frac{1}{7}$th of a day's supply. Plate 172 shows the distribution pipes as laid in the first instance. The system has now been extended to supply the portion of the town south of the river. The actual cost of the works amount to Rs. 81,000 or Rs. 3·3 per head. The actual maintenance charges amount on an average to Rs. 1,868 per annum.

Water Supply Works As Constructed For A Rural Town In The Presidency Of Madras: Plates 167 To 170.

Dharmavaram is a small Union in the Anantapur District of the Madras Presidency. The water works of this town were designed and executed by Mr. V. S. Gnanaprakasam and his report of this scheme was as follows: 1. The additions and improvements to the dispensary well consist of the following works: (*a*) Deepening the well to an additional depth of $12\frac{1}{2}$ ft. (*b*) Increasing the supply and capacity of the well by constructing four radiating adits in the form of a covered trench. Three

adits are to be 20 feet long each. The fourth adit will be 35¼ feet long extending beyond the dispensary compound wall. The end of this fourth adit is to be used as suction well for pumps. (c) Construction of a combined elevated tank and engine house with wire fencing. (d) A distribution system consisting of 4 double tap and 2 single tap fountains with necessary sluice, scour and air valves and capable of delivering the full supply of drinking water to the Petta or the northern part of the town including the bazaar. 2. The supply and capacity of the well will be increased when the improvements are carried out. This increase in capacity is necessary as it is only a percolation well. The fluctuations of water levels in wells at Dharmavaram vary as much as 18 feet between the highest water level in rainy season and lowest water level in summer. These fluctuations are proportional to the rise and fall of water in Dharmavaram irrigation tank. The particulars of the capacity of the existing dispensary well and the increase due to improvements referred to above are shown below:

Items for comparison.	Capacity of the well at its present state		Capacity of the well after it is improved.		Increase.	
	C. ft.	Gallons.	C. ft.	Gallons.	C. ft.	Gallons.
At highest water level in rainy season.	1630	10,186	17,805	105,787	1,546	96,601
At lowest water level in summer.	216	1,350	7,032	43,948	6,816	42,598

As the sub-soil is disintegrated gneiss or soft rock the adits will have vertical edge and shall be covered by granite slabstones as shown in plate 169.
3. The population of Dharmavaram Town is as follows:

As per census of	1871	...	7029
,,	1881	...	5916
,,	1891	...	6836
,,	1901	...	10658
..	1911	...	7386

The fluctuations or sudden decreases in population are due to the great famine of 1876-1878 and cholera in subsequent years. The dispensary well is expected to supply the estimated ultimate population of 5000 residing in the northern portion of the town called Petta after the additions and improvements provided in the estimate are carried out. In case the well is found to have a copious supply in excess of the requirements of the population of Petta, the distribution system may be extended to the other portions of the town at a moderate cost after duplicating the engines and pumps. 4. Engines and Pumps: The calculations made for the engines and pumps are as follow:

Ultimate population of Petta or the northern portion of Dharmavaram town	... 5000
Rate of drinking water supply provided is 8 gallons per head per day. Total supply required per day	...40,000 gallons
Hours of pumping	... 11
Quantity of water to be pumped per minute in 11 hours	... 61 gallons
Level of the foot valve in suction pipe	... 59·24
Level of delivery in the elevated tank	... 128·50
Static lift	... 62·26
Add for friction in bends and pipes	... 6·74
Total head	... 76 feet.

$$\text{P.H.P. required} = \frac{61 \times 76 \times 10}{33,000} = 1$$

$$\text{B.H.P. for 50 per cent. efficiency} = \frac{(100 \times 1{\cdot}48)}{50} = 2{\cdot}96.$$

Nearest market size available = 3¼ B.H.P.

Oil engines being economical, it is proposed to use Hornsby or Crossby's oil engines. The lowest summer water level falls very low as stated above. Therefore it is found necessary to place the pumps 18 feet below the ground level in a pump pit as shown in plate 169. Under these circumstances it is proposed to use Worthington's Single Cylinder double acting deep well geared pumps capable of pumping 100 gallons per minute assuming 60 per cent. for efficiency. Accommodation is provided in the engine house for 2 sets of engines and pumps but it is proposed to fit up only one set of engine and pump to commence with until the Dharmavaram Union is able to maintain two sets, and use the full supply of water. 5. The combined elevated tanks and engine house are situated outside the compound of the Dispensary as shown in plates 167 and 168. The details of the tank and the engine house are shown in plate 169. The type of stone masonry to be used for this work will be similar to that used in the Government buildings constructed at Dharmavaram. The covered wrought iron tanks provided in the plans and estimates are of the ordinary Railway pattern. They are four in number measuring 8′×8′×4′ each. The total capacity of these four tanks is 6,400 gallons or little less than one-sixth part of the total ultimate daily supply provided. This storage capacity is considered sufficient to meet the requirements of the population of Petta with pumping for 11 hours. 6. The distribution system consists of 4″ cast iron pipes, 99 feet long, and 3″, 2½″ and 2″ wrought iron pipes, 2,600 feet long, together with 4 double tap fountains, 2 single tap fountains, sluice valve, 1 air valve and 1 scour valve. It is capable of conveying 42 gallons per minute and distributing the ultimate supply of 40,000 gallons in 16 hours. The

details of hydraulic gradients are shown in plate 170. 7 The maintenance cost will be Rs. 1,092 per annum or Rs. 91 per mensem as detailed below: Cost of fuel per annum at one pint of liquid fuel per B. H. P. per hour and four annas per gallon $= \frac{11 \text{ hours} \times 3\ 25 \text{ B.H.P.} \times 365 \text{ days} \times \text{as. } 4}{8 \times 16} =$ Rs. 408

Cost of lubrication, cotton waste and sundries &c., per annum at 4 annas per day	...	91
Repairs to machinery, lump sum	...	101
Total cost of fuel, lubrication and repairs, &c.	,	600

Cost of establishment per annum:

1 driver on a grade of Rs. 20 to 30 per mensem for 12 months 25×12	Rs.	300
1 cleaner on a grade of Rs. 8 to 10 per mensem for 12 months (9×12)	„	108
1 watchman for 12 months on Rs. 7 per mensem	„	84
Total cost of establishment	Rs.	492

Total cost of maintenance per annum Rs. 600 plus 492= Rs. 1092.

Therefore average cost of maintenance per mensem is Rs. 91.

Conjeeveram Water Works.

" The town of Conjeeveram is situated 45 miles south-west of Madras in the valley of the river Vegavati. At the site of the town this river is 1,000 feet wide, although its source is only distant some nine miles and it possesses a deep sandy bed. Flood water is rarely seen in the river and the quantity is small. The river water has the reputation of flowing under ground through the sandy bed and thousands of acres of paddy are cultivated by spring or surface channels excavated in the sandy river-bed. The population of the town has risen from 37,327 in 1871 to 53,864 in 1911. In addition to this population a considerable number of pilgrims visit the town especially in certain months attracted by its holy Brahman character and the sanctity of its two famous temples. The larger temple is dedicated to Siva and the smaller to Kamachiamma. In order to protect the town from cholera, etc., water works were constructed in 1897, the designs of the same having been drawn up by Mr. H. Nowroji, Assistant Sanitary Engineer. The water works were designed for a future population of 56,000 and the rate of supply was fixed at 15 gallons per head. These works consisted of a gallery in the river-bed and a pumping station containing two sets of Worthington pumping engines which were used to pump water into the town through cast iron distribution pipes provided with the usual public fountains. The scheme as constructed was a direct pumping one, but in order to minimise the disadvantages of this system a small service reservoir was constructed from savings effected on the sanctioned estimate. The gallery as executed was 550 feet long and consisted of four rows of open jointed 9 inch stoneware pipes surrounded by broken stone filling of a total depth of 7 feet, of which 6 inches is below the barrel of the pipes. The bottom of the gallery was fixed at a depth of 20 feet below the river-bed at the left bank of pumping station site. The broken stone filling is believed to have been put in of $1\frac{1}{2}$ inch size. The four rows of stoneware pipes terminate in a collecting well on the river bank. From this well the water is conducted through a cast iron pipe to the suction well, the end of the pipe being provided with a reservoir sluice, so that ingress of water into the suction well can be cut off when this well requires to be examined. The suction well is 10 feet in diameter with 18 inches steining and was sunk to the required depth by divers. It is protected by roof of Mangalore tiles and is also ventilated. The suction well contains the suction pipes of the pumping engines and it is considered that the location of the well outside the engine house building site is satisfactory, preventing any trouble from settlement due to drawing in of sand which occurs into pump wells located in engine house sites and in sandy soil. The pumping plant consisted originally of two sets of horizontal Worthington pumping engines and locomotive type boilers. After the water works had been opened for some twelve years it was found necessary to install supplementary plant as the two existing pumping engines had to be kept almost constantly at work in order to supply the increased demand of the town. I recommended that the space left vacant in the engine house for a third set of Worthington pumping engines should be utilised for their installation, but it was subsequently decided by Government to install instead a suction gas engine working on Welsh anthracite. The installation of this gas engine necessitated the extension of the original engine house and this extension was made large enough to contain a fourth set of pumping engines of a type to be determined after experience had been gained of the working of the suction gas plant. Each steam pumping set is capable of pumping 583 gallons per minute against a total head of 56 feet. The suction gas plant is capable of pumping 584 gallons per minute against a total head of 69 feet. The water was distributed in the original scheme direct from the pumping station, the water main being 16 inches at the pumping station and decreasing in the town to 3 inches at the furthest point supplied. The distribution was therefore by direct pumping without the intervention of a service reservoir. Savings on the original scheme permitted the construction of a small masonry service reservoir in the town but at such a level that the higher parts were not benefited. This reservoir is used by

manipulating the sluice valves daily and the attendant disadvantages of the arrangement have been obvious for some years. The variation of pressure against the pumps does not permit of a constant length of stroke and consequently the cost of working is higher than it would otherwise be. The town is principally occupied by Brahmans and early after the opening of the works these householders obtained house connections without meters. The wastage of water at these house connections seriously affected the supply at public fountains and the higher parts of the town. Under the new Municipal Amendment Act power has been obtained to fix meters on house connections and to charge for excess water. As a rule Chairmen are averse to the actual fixing of the necessary meters, I suppose on account of its unpopularity; but these meters will require to be fixed if the wastage is to be controlled. The spill water at public fountains was usually run into roadside ditches where it stagnated causing a nuisance and encouraging the breeding of large numbers of mosquitoes. To remedy this state of affairs in the absence of a general drainage scheme I proposed the construction of filter trenches and wells. These were described as follow: In towns which possess piped water supplies and no proper drainage, it has been found that the spill water from fountains forms either objectionable pools or stagnates in the roadside earthen ditches. In these pools and ditches mosquitoes breed in large numbers and complaints have been made on this account alone. The spill water does not soak into the sub-soil at a sufficiently fast rate and it is necessary to devise means whereby the spill water will be immediately conveyed under the surface of the ground so as to prevent stagnation in pools and the breeding of mosquitoes. Two type designs (*vide* plates 179 and 180) have therefore been drawn up. The first one shows a filter well and the second a filter trench. It is proposed that a well (*vide* plate 179) should be constructed, close to a public fountain, into which the spill water would pass direct through a syphon trap. The well is shown as 4 feet in diameter and 8 feet deep. The bottom portion of the steining for 4 feet height will be well brick in mud and the upper 4 feet of the same brick in chunam mortar. The spill water will collect in this well and soak into the sub-soil. Any excess water received in the well during the day will soak away at night. The well top will be covered with stone slabs and a syphon disconnecting trap will be provided as shown to prevent any objectionable smell reaching the fountain platform. The well will be located on a favourable site in porous soil, the sub-soil water level being usually below the level of bottom of well. In such places where the well cannot be constructed close to a fountain, it will be constructed on adjoining land as near to the fountain as circumstances permit, the necessary connection being made by a pipe. The Sanitary Engineer has noticed at Conjeeveram that the spill water of certain fountains is led to a ditch passing the roots of cocoanut trees. Unfortunately the soakage of the water in these circumstances is not sufficient to prevent a nasty pool forming by the roadside. To avoid this, a type design (*vide* plate 180) for a filter trench has been drawn up. In this type design it is proposed to lead the spill water from a fountain suitably located into an open jointed sub-soil pipe surrounded by broken stone through which the soakage of the spill water into the sub-soil will be rapid. A small cistern at the beginning of the sub-soil pipe is intended for pipe-cleaning purposes. As in the case of the filter well, where suitable soil does not exist near a fountain, the spill water should be led away by a stoneware or iron pipe to the nearest suitable location for the filter trench. The cost of the "Filter well" at Madras rates will be about Rs. 50 and of the "Filter trench" Rs. 20. I am assured by the municipal authorities that these filter trenches have improved matters. Examples may be seen at Conjeeveram. The cost of the works originally proposed was Rs. 2,69,231 for a population of 56,000. This gives the low average cost of Rs. 4-8-0 per head of population. The low cost of the works is, in my opinion, principally due to the excellence of the site of the head works close to the town and on a river which is not subject to high floods or scouring action. The average annual cost of working was Rs. 16,363. The quantity of water pumped during the year was 234 million gallons, the average total height the water was lifted by the pumps being 34·14 feet. The cost of coal which was the fuel used for the steam plant was Rs. 18-12-0 per ton. The cost of Welsh anthracite suitable for the gas engine and delivered at Conjeeveram pumping station was Rs. 55 per ton. Owing to the small capacity of the low-level service reservoir and the fact that the distribution mains had been originally laid down for direct pumping, it has been found that it is impossible with present arrangements to supply all parts of the town with water at the requisite pressure. Proposals have therefore been drawn up for constructing an elevated service reservoir of 8 hours' capacity to be located at the pumping station site. It is also proposed to divide the town into three sections for supply and to lay new cast iron mains and carry out alterations in the existing ones. When this reservoir is completed, it will be possible to have pumping during the night so as to store water in the reservoir. The quantity of water to be supplied to the town will then be considerably more than the present supply. The quantity aimed at is 10,00,000 gallons daily."

Madras City Water Works.

"In addition to the 25 water-supply schemes constructed throughout the Presidency there is the important water supply of the City of Madras which has a present population 5,17,335 according to the 1911 census. Nearly forty years ago when the population was nearly 4,00,000 distribution pipes were laid down throughout the city and a supply of water was brought from a large irrigation tank situated at the Red Hills, 9 miles beyond the city boundaries, by an open channel to a masonry well located on the western boundary of the city. From this well which serves as a stand pipe the distribution pipes begin. These works cost originally 14 lakhs of rupees. In order to preserve the static level of the water as much as possible so as to make a gravitation scheme possible the outlet from the tank was constructed at such a high level that it was found necessary in years of deficient rainfall to supply the high level outlet to the channel with water pumped from the lower levels of the tank. For the same reason the channel as it approached the city was carried on a high embankment, which, it may be noticed, has stood wonderfully well. Owing to the increased demand for water and the trouble experienced from the deposition of silt carried forward from the open channel into the cast iron distribution pipes, plans and estimates for improvements were drawn up by Mr. H. Nowroji, Assistant Sanitary Engineer in 1905, and subsequently sanctioned by the Corporation and Government. This scheme provides for the tapping of the Red Hills tank at a lower level than the present channel outlet, the provision of a roughing filter near the outlet and the construction of a masonry conduit, 9 miles long, in lieu of the existing open channel. On the arrival of the water at the western boundary of the city it will be filtered through slow sand filters and partly stored in underground reservoirs and then pumped by steam pumps to an elevated tank whence it will be distributed to the city. The cost of these improvements was estimated at Rs. 24 lakhs and the works have already been executed. It is also in contemplation to improve the distribution pipe arrangements in the city at a cost of many lakhs of rupees so as to meet the demand from the increased population. The supply per head is also to be increased from the original provision of 16 gallons to 25 gallons."

Classification Of Existing Works.

"The 25 water-supply schemes constructed in the Madras Presidency may be divided into the following types: 12 Gallery schemes, 1 Well scheme, 9 Storage tanks with filters and 3 Storage tanks without filtration. This list shows that the water supply schemes are practically of two classes, the gallery type and the storage tank type with or without subsequent filtration. A gallery scheme of water supply is much in favour in Madras for two reasons. The first is the low cost of construction and maintenance and the second reason is the simplicity of working. Both of these reasons are of first importance in Madras owing to the fact that the water works are in charge of Municipal Councils who are unwilling to spend comparatively large amounts in construction, maintenance, and superior supervision."

Infiltration Gallery.

"An infiltration gallery as finally developed in Madras consists of a trench or gallery in a river bed and is usually from 20 to 30 feet deep. This gallery is excavated either across the bed or longitudinally in the direction of flow of the river according to the results obtained from preliminary investigation. This investigation consists first in the selection of a suitable site above the town and outlying villages to be as free as possible from contamination, and secondly by the putting down of 40 to 60 borings to a sufficient depth, say from 30 to 50 feet. These borings are put down in a longitudinal section up and down stream and at increasing distances apart, and on these results the further borings to determine the cross sectional conditions of the river bed are put down. In the majority of cases these borings either show a depth of fine and coarse sand ranging from 20 to 30 feet thick or alternate layers of sand and clay. In the former case the gallery depth would be determined by the available depth of water in the summer season with reference to the usual condition that there is no surface flow in the river during this season. In the latter case of alternate layers of sand and clay the gallery would be located so as to draw its principal supply from the deepest sandy layer, if of sufficient coarseness, and to rest on the underlying layer of clay. Samples of sand from the borings and from different depths would be taken and mechanically analysed to determine the coarseness of the sand and especially to observe the percentage of fine sand and silt contained in the coarse layers. The continuity and extent of the sand layers would also be calculated to determine the water contents. If the samples of sand were found to be satisfactory, that is to say, with a uniformity co-efficient of not less than 3, then it would be considered that the sand in the river bed was suitable for the location of a gallery therein. As many rivers in Madras have occupied in former times other positions, it is advisable to trace out by borings the old course of the river bed which is now dry land and to locate on this land the gallery itself instead of in the present bed. While the latest form of gallery adopted is a trench, there are several cases in which the gallery takes the form of an

underground filter bed protected by a barrage wall built across the river-bed and with the top of the wall submerged. The most successful galleries are those which have been located in a sandy river-bed. In the case of one of our works not in a river-bed where the gallery or trench was excavated in decomposed syenitic rock overlying hard syenite it has been found that, as is usually found in the case of wells in such rock, where the draw-off is considerable, the construction of the gallery or trench has permanently lowered the ordinary sub-soil water level. In this case the only solution for augmenting the supply is to extend the gallery, but this type is not one on which reliance can be confidently placed. In the case of galleries in sandy river-beds, those rivers receive from time to time floods which recoup the supply of water in the sandy bed. Diminution of supply in these galleries can be confidently met by the extension of the gallery preferably across the river-bed or if necessary in a longitudinal direction up stream. In this connection it may be noted that the extension of the gallery is only possible in those cases where the scour due to flood water does not reach more than 10 feet or so below the normal bed level. Where the scouring action of flood water would reach below this level a gallery placed across stream must be protected by a masonry wall on the down stream side. In those cases where the gallery is a longitudinal one and the river water in flood time exerts deep scouring action the site of the gallery would usually be on the bank of the river outside the scouring action of flood water. The trench type of gallery is constructed as follows: An open excavation is made in the river-bed in the summer season down to water level, and below this level the trench is excavated with the aid of timbering and sufficient pumping power to the depth desired which as already stated is usually 20 to 30 feet below river-bed level. The width of the trench will usually be 8 feet and at the bottom a layer of broken stone, 1½ inch size, is laid to a depth of 1 foot. On this layer one or two lines of open jointed stoneware pipes are laid with a slight fall towards a collecting well on the river bank. The trench is then filled in to a depth of 6 feet with broken stone, beginning with 1½ inch size and completing with ¾ inch size. The planking and shoring are removed as the filling proceeds and the construction pumps keep the water down to below the top of the filling. Above the ¾ inch size of broken stone, coarse sand is laid to a depth of 3 feet and above this layer the ordinary river-bed sand. The gallery is constructed in lengths of 100 or 200 feet according to the quantity of water to be pumped out, and this water is measured as the work proceeds so that data may be obtained of the available supply. As a rule, in those rivers of limited cross section and without perennial flow, the gallery is the first work to be constructed and until a test has been made of the quantity of water available, the remainder of the works including the supply of pipes is deferred. A question that is often asked is whether these galleries do not become rapidly choked. This, it is thought, is almost entirely a question of the percentage of fine sand in the deep coarse sand layers of the river-bed at the site of a gallery. Provided the percentage of fine sand is small there is no reason why such galleries should not work for 20 years or even longer. In the case of the gallery at Conjeeveram water works no trouble has been experienced from any movement of fine sand into the broken stone layers and stoneware pipes of the gallery and this after 15 years' working. In addition to absence of diminution in quantity, the quality of the water has maintained a high standard of bacteriological purity. It is however recognised that in cases of supplies from sandy river-beds where the sand contains a comparatively large percentage of fine sand which will pass through a sieve of, say, 100 meshes to the lineal inch and where the reduction in water level or infiltration head exceeds, say, 4 feet, there is every likelihood of this fine sand being carried forward into the interior of a gallery. In such cases it is considered that a gallery is unsuitable and the head works should take the form of wells which can be easily disconnected and periodically cleaned of the fine sand which may have entered the wells. In the case of the filter bed type of gallery with a protecting barrage wall which has had to be cleaned every five or six years, it is considered that the frequency of cleaning required is owing to the excessive head caused by the increased demand for water and the want of sufficient area of filter bed and also to the periodical floods depositing mud on the surface of the river-bed, this mud being carried into the interior of the filter bed by the powerful suction action of the pumping engines during the day's working. An infiltration gallery when constructed across the direction of flow of underground water in a river-bed enables us to obtain a much larger amount of water than would be obtained from wells sunk in the river-bed a considerable distance apart. It is thought that wells would require to be put so close as to actually abut each other before such wells could supply an equal amount of water to an infiltration gallery. This would mean that the infiltration gallery would be cheaper in construction than such wells when placed close together. If it were proposed to sink wells in a sandy river-bed at a considerable distance apart, say, 300 feet, it would be necessary to connect up these wells either to a common suction pipe or to a common syphon pipe. These pipes would then be located at a higher level than the bottom level of the wells and at this higher level such pipes would be liable to

damage by the scouring action of flood water. In the Trichinopoly water works we have an arrangement of three wells joined to a common suction pipe and this pipe has not only been carried away twice in the last nine years, but its presence at a comparatively high level above the bottom of the wells has given us constant anxiety for its safety. If the wells are not connected to a common suction or syphon pipe at a level higher than the bottom level of the wells, then these wells must be connected by a pipe at a low level usually at the bottom level of a well. This pipe would usually be of cast iron owing to the difficulty of jointing stoneware pipes at this depth in the presence of water. If the stoneware pipes were laid unjointed it would be necessary to surround them with broken stone so as to prevent ingress of sand and consequently this would mean the construction of an infiltration gallery. Such a gallery would not require to be supplemented by wells so that under the conditions described it would be preferable, in favourable locations, to adopt an infiltration gallery as the source of supply instead of a scheme of wells. In the case of the broken stone filling of a gallery, I am of opinion that in order to discourage movement of sand surrounding the broken stone it is an improvement to lay this broken stone filling, in decreasing sizes from the stoneware pipe in a similar way to the filling of a sand filter. This proposal is illustrated in plate 184. A well possesses this advantage over an infiltration gallery. Silt in the well or fine sand can be removed by means of a sand pump or a grab dredger. If silt has to be removed from an infiltration gallery this can only be done by actually removing the broken stone and relaying the same stone, after it has been cleaned. The silting of an infiltration gallery appears to be due to the presence of fine sand and silt in the river-bed. Where the quantity of this is large as at the Trichinopoly gallery, where it is 12 per cent. the silting of the gallery and also of the wells has been an undoubted fact. It has been found by mechanical analysis that 12 per cent. of the sand in the river Cauvery at Trichinopoly will pass through a sieve of 100 meshes to the lineal inch, and we look to this reason as the explanation of the indrawing of fine sand with silt into the infiltration gallery and the three wells in the river-bed which comprise the supply works. In the case of the Conjeeveram gallery the sand at depth is coarse and there has been no trouble from silting and no reduction in quality of the water since the works were constructed fifteen years ago."

Table Showing The Cost Per Lineal Foot, Etc., Of Infiltration Galleries.

Place.	Length of gallery.	Depth of gallery below ground.	Depth of gallery below L.W.L.	Expected daily yield.	Estimated cost.	Cost per lineal foot.	Cost per 1,000 gallons.
	FEET.	FEET.	FEET.	GALS.	RS.	RS.	RS.
Conjeeveram ...	550·0	17·03	7·00	560,000	13,793	25·0	24·6
Gudiyattam ...	207·0	15·16	8·50	150,000	5,130	24·8	34·2
Nellore ...	746·0	16·30	10·00	525,000	16,900	22·7	32·2
Trichinopoly ...	530·0	9·50	7·50	1,320,000	23,250	43·9	17·6
Vizianagram ...	400·0	26·0	...	750,000	10,300	25·75	13·73
Negapatam ...	1,200·0	15·0	...	1,233,750	35,080	29·23	28·43

6 | 171·4

Rs. 30·0, say, per lineal foot.

Storage Tanks.

"It has already been stated that the number of water supply schemes in Madras, of which a storage tank is a component part, is 12. These are usually provided where it is impossible to draw up a gallery scheme at a reasonable cost owing to the distance from the town of a suitable river with a sandy bed. These tanks are constructed preferably of a capacity equal to three years' supply in localities where the rainfall is low or variable. The result of storage in open tanks or lakes has been found to be highly beneficial to the quality of the water. The capacity of a tank requires to be enormously increased by provision for evaporation and absorption. This is usually taken in the case of water works tanks in Madras at half inch per day over the area at two-thirds of the depth of the tank, less the usual recoupment during the period. Although it is recognised that all cultivation should cease within the catchment of a storage tank yet for financial reasons it is found impossible as a rule to insist on this and we have to be content with the acquisition of land within 1,000 feet of the line of water spread at maximum water level. In the case of a tank which had laterite earth on the surface within the catchment area, heavy rain in the monsoon months resulted in the water of this tank becoming red in colour, and with a large proportion of mud in suspension. This laterite mud owing to its fineness, was found to be incapable of deposition even after several months and the sand filters which were in

use gave great trouble owing to their frequent clogging. The introduction of mechanical filters for roughing purposes was therefore seriously considered when owing to the acquisition of certain cultivated dry land within the catchment area the presence of laterite earth in suspension in the tank water suddenly ceased thus obviating the necessity for mechanical filtration. It is therefore suggested that in similar cases the prevention of cultivation of dry land of certain kinds within the catchment of a tank is advisable. From the analyses of the waters of storage tanks in Madras it is considered that, provided there is no abnormal amount of silt in suspension, the provision of 1,000 feet margin around the maximum water level by the acquisition of land 1,000 feet in breadth is a sufficient protection against the contamination of the tank water by the run off, from the rest of the catchment even when cultivation is carried on in the remainder of the catchment area to a considerable extent. This statement is however subject to the condition of sufficient storage in the tank and to the draw off of water 3 feet below the highest level available either by a floating pipe or by a draw off stand pipe with valves at different levels. Our tanks are being constructed with embankments or bunds 9 feet wide at the top and with front slopes $1\frac{1}{2}$ to 1 and rear slopes 2 to 1. In the future, it will however be better to adopt slopes of 2 to 1 and 3 to 1 respectively so as to minimise leakage from the tanks and to obtain a stronger embankment. The front slope is usually pitched with stone 18 inches thick over gravel 12 inches thick."

Filter Beds.

"The only filter beds in use in Madras at present are of the ordinary sand filter type and these have given very variable results in the past owing to want of superior supervision by the Local Bodies. The type (*vide* plate 185) in use is the ordinary European type consisting of a masonry tank, rectangular in form, filled up with 2 feet of broken stone of size $1\frac{1}{2}$ inches to $\frac{3}{4}$ inch and sand of varying coarseness the first layer above the $\frac{3}{4}$ inch stone being sand, retained on a sieve of 10 meshes to the lineal inch, to a depth of 4 inches, the sand above this layer being that which will pass through a sieve of 10 meshes and be rejected on one of 40 meshes. This layer is 2′ 8″ thick. Above the top sand layer the minimum depth of water is 3 feet. Our experience of sand filters in the Madras Presidency has been disappointing. Shortly after the filtering material in a filter bed has been relaid the filtrate has given excellent results but as a rule the bacteriological analyses of samples by the Maconkey system has shown variable results either from want of attention to the working, indifferent sampling, tropical conditions in Madras, or the system of analysis itself. Accordingly, I recommended to the Madras Government, and they have since sanctioned, the installation at a cost of Rs. 34,000 of experimental filters, both ordinary sand filters and mechanical filters to be erected at the King Institute, Guindy, in order that some practical conclusion could be arrived at as to the actual working of filters under Madras conditions. It has been suggested that the broken stone layers of a sand filter should be reduced from 2 feet to 1 foot in thickness in order to reduce multiplication of bacteria in the post filtration passages. This proposal appears to be contrary to the practice in Europe, but the experimental sand filters to be erected at the King Institute will show by actual results from samples taken at different depths what actually happens, out of sight, in a filter bed. Another proposal to reduce the depth of water from 3 feet to 2 feet in order to reduce the total depth of a filter bed, we have already negatived by experience of working with such a depth in the Coconada filters. Owing to the rapid growth of algæ in the shallow water, it is found necessary to revert to the provision of a minimum depth of 3 feet. In connection with the position of sand filter beds in relation to the storage tank, our experience in Madras has shown the necessity for their construction at some distance from the storage tank or in some position where the normal sub-soil water level will be below the level of the floor of the filter bed in order to avoid the coming in by diffusion through cracks, of sub-soil water into the bed below the sand layer. Inlet valves are automatically regulated and the outlets are provided with Glenfield-Jones automatic filter outlet apparatus so as to ensure the steady draw off from each bed of a quantity of water not greater than 450 gallons per square yard per day. These outlet automatic valves are also so set as to limit the maximum head of draw off to 2 feet. As the supply to the towns is usually only for 16 hours in the day time at the rate of 15 gallons per head, storage is provided in covered reservoirs of 8 hours' supply for the water filtered at night." In plate 186 is shown a design for filter beds and service reservoir suitable for rural water supplies.

Water Supply Arrangements For A Public Building: Plate 171.

In plate 171 is illustrated the design of a water supply installation for a public building drawn up by Mr. Hutton. His report accompanying this design was as follows: These arrangements are suitable for the supply of water for a public building when a source of supply such as a well can be found within a reasonable distance of the building. The arrangement consists of a well, 10 feet in diameter, and 20 feet deep and a boreho

sunk through the middle of the well to tap an underlying stratum containing fresh water. The water from the well will be pumped out by means of a double barrel lift and force pump, the power being provided by an oil engine of the smallest size available, say, about 2 B.H.P. In the event of the breakdown of the engine the pump will be worked by manual power, 4 coolies by means of handles which can be attached to the axle. The engine and pump will be contained in a small corrugated iron shed. The size of suction pipe will be $2\frac{1}{2}''$ and that of the delivery pipe to the storage tank on the top of the building will be also $2\frac{1}{2}''$. Branches can be taken off of this delivery pipe wherever required. The storage tanks on the roof of the building are not included in the estimate as they are provided with the building. The cost of the proposals that is, for the well, engine house, engine and pump, suction and delivery mains and the borehole in the bottom of the well is estimated at Rs. 5,500.

Abstract Of Quantities For Water Supply Arrangements For A Public Building: Plate 171.

Quantity.	Description of work.
5321 c. ft. ...	Earthwork, excavating including re-filling.
7 r. ft. ...	Sinking 10 feet well.
sum. ...	Wooden well curb including angle iron cutting edge with bolts, bonding rods etc.
7246 c. ft. ...	Brickwork in surkhi mortar.
1717 sq. ft. ...	Plastering with cement, $\frac{1}{2}''$ thick.
sum. ...	Hyrib flooring including manhole cover, rolled steel joist, fixing, etc., complete.
10 r. ft. ...	Flat bottom rail including fixing.
sum. ...	Pumping charges during construction.
" ...	Cement concrete flooring 2" thick, including plastering, cast iron collar for boring pipe.
652 c. ft. ...	Earthwork, excavation.
111 c. ft. ...	Brickwork in surkhi mortar.
74 sq. ft. ...	Plastering with cement, $\frac{1}{2}''$ thick.
293 sq. ft. ...	Flooring with Cuddapah slab, 2" thick, on 4" concrete and pointed with cement to full depth of slab.
sum. ..	Corrugated iron sheet walling and roofing including iron posts, principals, purlins, horizontals, one door and two windows, bolts, base plates, fixing, painting, etc., complete.
" ...	Double barrelled "A" frame lift and force pump, size of suction and delivery $2\frac{1}{2}''$ with pulleys and hand wheel, Fig. N page 49 of Messrs. Richardson & Cruddas catalogue including $2\frac{1}{2}''$ suction and delivery pipes to tank; foot valve and strainer; laying and jointing pipes, fixing pumps including foundation bolts etc., complete to pump 1500 gallons per hour.
sum. ...	2 B.H.P. Oil engine with necessary cooling water tank pipes and connections, exhaust pipes and silencer; foundation bolts and standard pulley, belting, fixing, etc., complete.
	110 ft. of boring, 4" diameter, including boring pipes, labour, hire of tools, etc., complete.
"	Contingencies and petty charges.
	Total Rs. ...

Continuous Supply.

"The provision of a continuous supply although highly desirable is not one which ordinary mufassal councils require and if given under present conditions would result in the wastage of almost the whole of the night's supply. Until lately the powers of regulation were so limited by the provisions of the District Municipalities Act that it was found impossible to safeguard consumption of water especially at night. Since then an Amendment Act has been passed which gives the Chairman of a Council necessary powers to fix meters and to enforce rules against wastage of water. It is therefore hoped that there will be less wastage in the future than in the past which wastage was encouraged by the early introduction of certain water supplies prior to adoption of rules and by-laws for regulating consumption."

Classes Of Water Supply Schemes.

Having described in detail the general features of water supply schemes in this Presidency, I propose to discuss the classes of water supply schemes. Judged from the different sources of supply, the water supply schemes may be classified under: 1. Tank schemes. 2. Schemes of surface water from canals, channels, perennial rivers and streams. 3. Shallow infiltration gallery schemes. 4. Schemes of shallow infiltration galleries and wells combined. 5. Submerged infiltration gallery schemes. 6. Infiltration well schemes. 7. Deep well or Artesian supply schemes. 8. Schemes of infiltration gallery and storage combined. Judged from the methods adopted for purification of water, the schemes of water supply may be classified as 1. Unfiltered surface water supply; 2. Well and gallery supplies; 3. Supply filtered by sand filters; 4. Supply filtered by mechanical filters. Judged from the levels of supply sources and towns, the schemes are classified under: 1. Gravitation, see figure 1, plate 148. 2. Pumping, see figure 2, plate 148. 3. Gravitation and pumping combined, see figure 4, plate 148. 4. Pumping and gravitation combined, see figure 3, plate 148. 5. Pumping, gravitation and pumping combined.

WATER SUPPLY: DATA FOR PRELIMINARY PROPOSALS, THE METHOD OF DRAWING SAMPLES OF WATER FOR CHEMICAL EXAMINATION FROM WATER TAPS, TANKS AND STREAMS: AND THE QUANTITY OF WATER NECESSARY PER DIEM PER HEAD FOR A TOWN POPULATION AND FOR HORSES AND OTHER ANIMALS.

Population.

The population as per last 5 censuses of every city, town, division and firka is available. The scheme to be designed is generally for a prospective population some 30 or 40 years from the time the scheme will be first brought into operation. Conditions such as (1) introduction of Railways, (2) establishment of new Government administrative offices, Courts, etc., and (3) other local causes should be taken into account in considering the amount of probable prospective population of any place. An over-estimate of population will result (1) in the initial cost being prohibitive, (2) in excess of the life of the component parts of water works. An under estimate of population will result (1) in the requirements being larger than the supply shortly after introduction, and (2) in the necessity to provide additional works before the component parts run out their life. For example, the probable prospective population of Bautual in 1951 is thus obtained. The population as per 1881 census was 3,985. Population as per 1871 census was 3,685. Increase was 300 or 8·14 per cent. Population as per 1891 census was 4,328. Population as per 1881 census was 3,985. Increase was 343 or 8·61 per cent. Population as per 1901 census was 4,448. Population as per 1891 census was 4,328. Increase was 120 or 2·77 per cent. Population as per 1911 census was 4,985. Population as per 1901 census was 4,448. Increase was 537 or 12·07 per cent. Population as per 1911 census was 4,985. Population as per 1871 census was 3,685. Increase was 1,300 or 35·3 per cent. From the above it will be seen that the maximum percentage of increase of 12·7 occurred between 1901 and 1911. On this basis, the probable population of 1951 will be 1911, 4,985; 1921, 5,618; 1931, 6,334; 1941, 7,135; 1951, 8,017. On the basis of the percentage of increase in the 40 years 1911—1871, *viz.*, 35·3 per cent, the probable population of 1951 would be 6,715. It is usual to adopt the higher, *viz.*, 8,017 of the two results. The prospective population is often obtained graphically as shewn in plate 149.

Quantity.

In this Presidency, the usual practice is to provide 15 gallons per head per day. The new scheme of the city of Madras is worked on a 25 gallon basis. In cases where funds are very limited, the minimum quantity to meet sanitary requirements is taken as 7 gallons per head per day. The amount of water required by the population of towns varies considerably in one town from another. In the book on Hygiene by Notter and Firth, the details of requirements are given as under: Cooking, ·75 gallons; drinking, ·33 gallons; baths, 5·00 gallons; house washing, 3·00 gallons, laundry washing, 3·0 gallons, general baths, 4·00 gallons; water closets, 6·00 gallons; unavoidable waste, 2·92 gallons: total 25·00. If special provision is required to be made for the supply of water to animals, the minimum quantities usually allowed are as follow: For elephants, 25 gallons; for oxen large, 6 gallons; for oxen small, 5 gallons; for horses, 8 gallons; for mules and ponies, 6 gallons; for sheep and pigs, 1 gallon. In the military water supplies, a provision of 20 gallons per horse is usually made. No useful purpose will be served by comparing figures shewing quantities of water supply schemes of different towns in this Presidency, as the available figures are not sufficiently accurate to permit of positive results. For villages a provision of 7 to 10 gallons per head seems sufficient especially to avoid the evils of an abundant supply in the absence of drainage works. For mufassal towns, a provision of 15 gallons per head per day is reasonable. Having determined the quantity of supply per day, the rates of delivery per minute may be discussed under the three heads; *viz.*, (*a*) requirements for town consumption; (*b*) requirements for gravity supply to service reservoirs; and (*c*) requirements for pumping.

Requirements For Town Consumption.

The rate of hourly consumption varies in different towns. The expression, "average supply" is used in water works to mean the supply per minute

during 24 hours, that is, average supply equals prospective population × rate of supply per head per day, divided by 1,440. In drainage schemes, this quantity is termed, 'Dry weather flow.' In practice there is a larger demand for water during certain hours of the day than the demand during the other hours of the day. The consumption during nights nearly consists of wastage and leakage. The hours during which the rate of consumption per minute is highest are termed 'Periods' or, 'Hours of maximum demand or consumption.' The expression, 'maximum supply' means the rate of supply during the periods of maximum consumption. The duration of the periods of maximum consumption varies from 6 to 8 hours and the maximum rates also vary from 1·30 to 2·38 of the average rate. In this Presidency the maximum rate of consumption has been fixed at double the average rate and the duration of periods of maximum consumption is taken as 6 hours, usually the periods 6 to 9 A.M. and 3 to 6 P.M. daily. The distribution pipes in a town are designed capable of carrying the maximum supply or double the average supply. During the other 6 hours of the day, *viz.*, between 9 A.M. to 3 P.M., and during six hours of the night, *i.e.*, between 6 P.M. to 10 P.M. and 4 A.M. to 6 A.M., the rate is taken as the average supply. For purposes of the determination of sizes of service reservoirs or other component parts of water works, it is presumed that there is no town consumption between 10 P.M. and 4 A.M. during nights.

Requirements Of Gravity Supply To Service Reservoirs.

The pipe from H to K in fig. 4 of plate 148 is called "gravity supply main or pipe to service reservoir." This pipe is designed capable of carrying the average supply. As the pipe to supply the town, *viz.*, F to G in fig. 3 of plate 148 should be capable of carrying the maximum supply, it would be financially advantageous to locate the service reservoir as near the town as possible.

Requirements For Pumping.

In pumping schemes (see figs. 2, 3 and 4 in plate 148), the pumping plants can be made suitable for pumping the daily requirements in 8, 12, 16 or 24 hours as required. The duration of pumping hours daily is a question which depends on (1) character of the sources of supply, (2) provision of service reservoir, (3) class of pumping plant, and (4) financial considerations. If the supply works consist of a gallery or wells and if the rate of inflow at the head works equals the rate required for the town during every minute of the 24 hours of the day, pumping should be done all the 24 hours. If pumping hours are reduced from 24 hours it would then be necessary to provide collecting reservoirs to store water. If a service reservoir is provided for and if the rate of supply at the head works will permit of reduced durations of pumping, then the periods of pumping may be fixed as 8, 12 or 16 hours as desired. There are certain classes of pumping plant in which it is advantageous to work them continuously all the 24 hours. In some cases, it will be found advantageous to provide a larger power plant and reduce the hours of pumping. The financial aspect is the chief point on which the duration of pumping hours is fixed in each case. The determination of this question is dependent on a number of considerations as stated above and it is impossible to give a hard and fast rule applicable to all cases. As a general rule, it may be stated that pumping schemes in which coal, firewood, oil, liquid fuel, charcoal or anthracite is fuel for the plant, it is advantageous to fix the pumping hours continuously for the 24 hours and to provide a service reservoir of minimum capacity of 8 hours' average supply as an essential component part of water works. Having determined the hours of pumping, the rate of delivery per minute is then a simple matter of arithmetic, *viz.*, daily supply in gallons divided by hours of pumping × 60.

Quality.

As a rule, people evince a deeper interest in regard to quantity than in regard to quality. I am no medical man and I do not therefore propose to enter into a discussion of this question from hygienic or medical standpoints. This question will therefore be discussed under the following heads: (1) Methods for field tests to determine whether the water from a proposed source of supply is worth being forwarded for bacteriological examination and chemical analysis. (2) Rules to be observed in taking samples of water for bacteriological examination and chemical analysis. (3) Interpreting the results of tests as furnished by Medical Sanitary specialists.

Methods For Field Tests To Determine Whether the Water From A Proposed Source Of Supply Is Worth Being Forwarded For Bacteriological Examination And Chemical Analysis.

The chemicals and apparatus required are: A. Outfit No. 1 in a teak box containing (1) one 4 oz. glass stoppered bottle containing standard solution of silver nitrate made by dissolving in the proportion of 4·79 grammes of pure silver nitrate in one litre of distilled water; (2) one 4 oz. glass stoppered bottle containing yellow potassium chromate solution made by dissolving in the proportion of 220 grains of yellow chromate in 10 oz. of distilled water; (3) one 4 oz. glass stoppered spare bottle;

(4) one oz. measure; (5) one minim measure; (6) four glass test tubes and (7) three pipettes B. Outfit No. 2 in a teak box containing (1) one 8 oz. glass stoppered bottle containing dilute sulphuric acid; (2) one 4 oz. glass stoppered bottle containing dilute solution of potassium permanganate; (3) three 10 oz. glass stoppered bottles spare; (4) one oz. measure, and (5) one minim measure; (6) two pipettes; and (7) two glass tumblers. The tests conducted in the field are (i) for clearness and colour by observing the depth of water, as compared with distilled or other known potable waters, through which a newspaper can be read; (ii) for odour by shaking up a portion of water in a clean wide mouthed bottle; if none is detected the water should be set aside and again examined after 24 hours have elapsed; (iii) for chlorine by using ½ oz. of sample water and adding two drops of chromate solution to give it a yellow colour; then add drops of silver nitrate solution (outfit No. 1) till the sample turns red and compare with the number of drops required in a known potable water and (iv) for oxygen absorption by taking 8 oz. of the sample of water in question and 8 ounces of a sample whose potability is known in two stoppered bottles and add to each the same quantity of dilute sulphuric acid, then add a few drops of a dilute solution of potassium permanganate to one and then the same number of drops to the other; let them stand and at the end of 4 hours compare the tints of the solutions; if the tint of the sample of water under test is weaker or completely gone it absorbs more oxygen. The above are the tests usually conducted by surveyors in the field. The following extract from Mr. J. A. Jones' Manual will be found useful for those who desire to conduct further field tests. "Microscopic examination may be made and it should be noted whether the sediment contains evidence of contamination such as rice or other grain, hair, fibres, wool, etc. The water may be chemically examined thus: (1) for reaction (acidity or alkalinity) by the immersion of blue and red litmus paper in the water. Good water ought to be neutral or faintly acid (from carbonic acid). The papers should, therefore, remain unchanged in colour or the blue paper become purple or faintly reddish. If the red paper becomes purple or blue, the water is alkaline. A strongly acid or any alkaline reaction should condemn a water unless the cause is known to be harmless. (2) To test for organic matter, obtain two white glass bottles, a solution of 1 grain to 2 ounces of water of permanganate of potash and some distilled water. Fill into each of the bottles the same quantity of water, into one bottle the distilled water, into the other the water to be examined. Add to each a portion of the solution drop by drop until a pink tinge is acquired. Place both bottles against a sheet of white paper and examine for a quarter of an hour. The loss of the pink colour rapidly shows the water examined to contain a large amount of organic matter probably animal, if it loses its colour slowly, the organic impurity is more probably vegetable; if the pink colour remains, the water contains little organic impurity. If, however, a water has iron in it, this will cause the loss of the colour. To detect iron in a water, if in any quantity the taste will indicate its presence; if in small quantity, evaporate a portion of the water to dryness and add a drop of solution of potassium ferrocyanide to the residue; a blue colour indicates the presence of iron. To detect ammonia in water: Obtain Nesseler's solution which is made as follows: 30 grains potassium iodide and 10 grains mercuric chloride are dissolved in a pint of warm, distilled or rain water; a strong solution of mercuric chloride is added drop by drop, stirring until a slight red precipitate is formed. 150 grains of caustic potash is now added and finally a little more mercuric chloride solution until a slight precipitate is produced. Allow this to subside and decant the clear solution for use. Drop a little of the solution on the water. A yellow or brown colour indicates the presence of ammonia or its salts. If a white milky precipitate is produced, lime or magnesia is present. This test is therefore a double one, the depth of brown or yellow colour depending on the amount of ammonia, and the degree of hardness on the amount of the whitish precipitate. To test for chlorides, add to the water in a test tube a few drops of nitrate of silver acidulated with nitric acid, the presence of chlorides will be shown by a milky haze or precipitate. To test for sulphates, add to the water in a test tube some drops of barium chloride acidulated with hydrochloric acid. Shake up and if a haze is produced, sulphates are present. Magnesium salts are indicated by the production of a similar cloudiness on shaking after the addition of ammonia solution to a water. The inferences to be drawn from the above examination and tests are: (1) Colour, turbidity, odour or taste may be a sufficient reason for the rejection of a water, but a colourless, odourless, or tasteless water is not necessarily pure and fit for consumption. (2) Strong acid or alkaline reactions should condemn a water, unless the reason is known to be harmless. (3) Water which rapidly decolourises permanganate of potash, is dangerous from the presence of organic matter unless iron is present. (4) Water in which there is a well marked colour produced in the ammonia test is polluted, as ammonia is usually derived from the decomposition of nitrogenous organic matter. If there is much white precipitate produced, the water is bad for cooking and washing, but may be suitable for drinking, if magnesium salts are not indicated by the test for these salts.

(5) Chlorides are present in most waters, a large quantity shows the water is brackish. This quality may be derived from the soil or it may be animal impurity. Thus a considerable quantity of chlorides alone cannot condemn a water. (6) The presence of sulphates is evidence of dangerous mineral or organic contamination. (7) Mangesium in sufficient quantity to give turbidity ought to condemn a water. Such tests and considerations will afford a basis for opinion as to the suitability or otherwise of water, but in no case should any source of supply, especially for domestic purposes, be decided upon until a complete analysis by a chemist has been obtained. It is advisable also to have the water drawn from a proposed source at the various times of the year, so that the effect of seasonal variations may be noticed, and it is no less necessary that town supplies should be regularly and carefully examined so as to guard against contamination and to ensure the continued efficiency of the means taken to prevent contamination."

Rules To Be Observed In Taking Samples Of Water For Bacteriological Examination And Chemical Analysis.

The duty of sampling water is a responsible one and should not be entrusted to subordinates, especially to the class of subordinates who consider their duty in the matter of sampling of water only entails the performance of collecting a sample without in the least equipped with knowledge as to (1) why the sample is taken, (2) where the sample should be taken, (3) how the sample should be taken, and (4) the direct and indirect consequences of bad sampling of water as a result of ignorance on the part of the sample taker. As a rule, the responsible work of the sampling of water should be done by the District Medical and Sanitary officers and Health officers personally. In localities and circumstances in which the services of the above officers are not available, the work of sampling of water should be entrusted to responsible Gazetted officers with full and complete instructions if they are new to the work. Occasions will arise when the duty of sampling of water may devolve on junior subordinates. I will therefore discuss rather fully under this head all about 'sampling of water.' In the Presidency of Madras, the bacteriological examination and chemical analysis of sample water are conducted at the King Institute of Preventive Medicine, Guindy, and reports with statements of results of tests are furnished by the Director of the Institute. The director's results of his laboratory work and his reports on the results are based on the sample of water received by him. If the report and results are to be relied on to form an opinion of the water whether such opinion is required for determining (1) the suitability of water for potable purposes, (2) the efficiency of the purification works of an existing water supply scheme, and (3) the condition of the distribution pipes of a water works scheme, it is essential that the specimen must be the right sample. A sample of water taken at the wrong spot, at the wrong time and with erroneous methods of procedure while taking it when analysed and reported on by the Director of the King Institute is sure to land all concerned in serious difficulties. I will describe some of the possible results of bad sampling of water. In regard to new proposals, by relying on the results of a bad sample, you may be driven to the necessity of abandoning a near source of supply or proposing costly purification works. For want of funds to adopt the farther source of supply or to provide costly purification works, the proposal for water supply may be thrown in that shelf labelled "Proposals shelved for want of funds" in which we have already recorded a lot. It is not sanitarily safe to record any more in this shelf. A really suspicious or unusable water might be certified by bad sampling as 'good water.' The consequences in such cases will result in the opposite of the benefits contemplated by the introduction of a water supply scheme. The results of bad sampling of water from existing water works lead to the people and local authorities being over-confident of the purity of their supply, in spite of the warning of the general health conditions in some cases. In others, unnecessary concern and anxiety sometimes supplemented with proposals of a costly nature for improvement result. In the case of Gudiyattam water works which I have described at length in a previous lecture, the water is the sub-soil water of a river. According to rules, three samples of water are usually analysed, *viz.*, (1) unfiltered water, (2) filtered water and (3) tap water. In this case what is intended for the sample of 'unfiltered water' is the surface flow of the river at site of gallery, if at the time the sample is taken there is surface flow. If then, there is none in the river, I am not to take a sample of water from a disused or polluted tank in the town because (1) "the tank is at Gudiyatham," (2) "the water in it is unfiltered and fully answers to the description given in the printed statement given to me" and (3) "the previous records shew no instance when the sample of unfiltered water had not been taken." But I would enter opposite the heading "unfiltered water," the following remark, "no surface flow and therefore no sample is furnished." As regards the sample 'filtered water' I would take the sample of water in the collecting well, suction well or the tap in the pumping house in the manner described later on. I would not label this sample blindly as 'filtered water' but the label will be "water after passing through infiltration gallery taken at......

No filter works in the scheme." Regarding the sample of tap water in the town, I will not take a sample from a 'cattle trough or an open cistern in a market.' The results of this sample are intended to disclose the condition of the distribution pipes. This sample should be taken *after* having the pipe scoured out according to instructions furnished by the Sanitary Engineer to the Government of Madras. Let me now generalise and trust you will remember the following essential conditions. A. Existing works: I. Unfiltered water: (*a*) Source of supply, storage tanks, surface flow of streams, rivers, canals, and channels: The sample should be taken just at or near the existing or proposed draw off arrangements some distance from the banks, some 3 or 4 feet below the water surface or at mid-depth if depth of flow is less than 3 feet, excluding any floating scum and avoiding the stirring up of mud; if sedimentation or setting tanks exist, a further sample taken at the outlet chamber of the tank should be furnished to the analyst; (*b*) source of supply, underground flow from infiltration galleries, infiltration wells, located in the beds of rivers; if there is surface flow at the time of sample taking, take the sample just at or near the gallery or well, some distance from the banks, some 3 or 4 feet below the water surface or at mid-depth if depth of flow is less than 3 feet excluding any floating scum and avoiding any stirring up of mud. If at the time samples of water are taken, there was no surface flow, enter the remark, "no sample of unfiltered water is furnished as there is no surface flow in the river on.... ;" (*c*) source of supply, underground flow from infiltration galleries or wells located on river margins or other areas of water bearing stratum; no sample should be furnished but the following remark should invariably be entered, "no sample of unfiltered water is furnished as the supply is drawn from a gallery or well located outside the beds of rivers." II. Filtered water: (*a*) Schemes provided with sand or mechanical filters: In these cases take the sample from the tap specially provided for the purpose at each place after allowing the first water to run to waste for at least 15 minutes. Do not scoop up the scum at the outlet chamber of a sand filter and designate the sample as 'filtered water.' (*b*) Wells, collecting chambers of infiltration galleries: Always enter the remarks "Well water" or "Water after passing through infiltration gallery taken at 'sample tap' provided for the purpose." If samples are necessarily to be taken from wells, take the samples at least 2 feet below the surface water level. If sample taps are available, take care to run to waste the first flow for at least 15 minutes before the sample is drawn. III. Tap water: Take the sample from a tap after scouring the supply pipe in the usual manner described in a subsequent paragraph and after the first flow of water from the tap is allowed to run to waste for at least 15 minutes. B. Samples for new proposals: I. Surface water from tanks, streams, rivers, canals and channels: Samples should be taken exactly as described for A. I (*a*) above. II. Water from bore-holes: The following are extracted from Mr. Hutton's printed Circular dated February 1908. (*a*) For three days prior to the date when the samples are to be taken, the water in the bore-hole should be pumped out steadily by continuous pumping for at least six hours each day by a suitable hand pump. (*b*) Care should be observed that the rate of discharge of the pump does not exceed the rate of inflow into the bore-hole. As a rule, the reduction in depth of water in the bore-hole should not exceed 3 feet to avoid in-drawing of sand and earth in the bore-hole. (*c*) Immediately before taking samples, the water in bore-hole should be pumped for at least three hours. (*d*) It is expected that the sample taken after such continued pumping will be clear and free from contamination. Before filling the sample bottles, the water from bore-hole should be taken in a clean glass tumbler and examined. If the water is not clear, then the pumping should be continued slowly and very steadily till clear water is obtained. In some cases, it may be ultimately necessary to accept samples which are not clear. (*e*) The samples should only be taken as a general rule when water in glass tumbler is seen to be clear water. III. Water from existing or experimental new wells: (*a*) The water in wells should be pumped out dry, and bottom of well thoroughly cleared of silt, debris, etc. In cases where sufficient powerful pumping plant cannot be made available and when it is impossible to empty the well with ordinary kavailais, picottahs or hand pumps, the well water should be pumped continuously for a period of 7 days working at least 8 hours daily keeping head of water as low as the available pumping power would permit. In cases where powerful pumping plant is available, clean the well of silt and debris after emptying the water in well and pump the water in well with a steady head of 5 feet for 3 days continuously. (*b*) Immediately before taking the samples, the water in well should be kept, by pumping for 3 hours, at a constant head not exceeding 5 feet. (*c*) Before filling the sample bottles, the water from well should be taken in a clean empty bottle and examined to ascertain if clear water, as judged by the naked eye, is obtainable. (*d*) The samples should be taken at a depth of 1 or 2 feet below the surface level of well water.

General Rules Regarding Sampling Of Water.

1. Before proceeding with the preliminaries to take the samples for quality tests, ascertain from the analyst as to date which will suit him to carry

out the necessary tests. As the analyst has usually a number of samples to be tested, always suit to his programme and send the sample to reach him exactly on the date fixed by him. (2) The filled sample bottle for Chemical analysis should be labelled as follows: (*a*) Description of place and scheme. (*b*) Description of water, *i.e.*, water of tank, canal, channel or stream, well or bore-hole as the case may be. (*c*) Date of Collection. (*d*) Reference letter No. and date. (*e*) Signature and designation of officer taking the sample. (3) The sample for Chemical analysis should be packed in a dealwood box and should be forwarded to the analyst by the earliest mail train or by bearer and the box itself should bear legibly on the outside. "By "Bearer," or "By Mail," "Top" "Glass with care," "Train-Paid," "Water sample for chemical analysis," and address of the analyst, with sender's address on the left hand corner. (4) The samples for bacteriological tests, should be taken exactly as per following instructions in the circular furnished by the Director of the King Institute, Guindy. "1. The bottle is forwarded in the original wrapper in which it was sterilised. The wrapper should not be removed until the instructions have been read. 2. On reaching the source of water, and not before, the upper part of the wrapper should be torn open so as to expose the neck of the bottle. Avoid touching any of the contained parts with the hand. 3. Place the piece of paper torn off turned with its sterile side upwards. 4. Steadying the bottle, by grasping outside the wrapper, loosen the stopper with the finger and thumb taking care not to touch the neck and place it on the torn sterile paper. 5. (*a*) In the case of tap, allow the water to run down at least 5 minutes before the bottle is opened and sample collected. (*b*) In the case of a well attach a long string to the end of the sterilised string which will be found tied round the neck and lower the bottle into the water and allow it to become nearly full. 6. Raise the bottle and replace the stopper taking similar precautions as when removing. 7. Place bottle on the ground, screw home stopper, replace the sterile paper and tie on with string. 8. Label outside the wrapper." (5) The sample bottle should then be packed in a dealwood box with plenty of ice and despatched always by bearer who is to be instructed to replenish the ice now and then till it reaches the laboratory. (6) Every sample of water should be sent in separate dealwood boxes superscribed, "Top", "Glass with care," "Sample for bacteriological examination." The following particulars should also be given in the superscription: 1. Description of place and scheme; 2. description of water, *i.e.*, water of tank, canal, channel, river, or stream, well or borehole, as the case may be; 3. date of collection; 4. reference letter, number and date; 5. signature and designation of officer taking the sample; 6. address of the analyst. A card board with above particulars may be nailed to the top of the box. (5) Bottles for samples should be obtained from the analyst. (6) With the forwarding letter, the printed form obtainable from the Director of the King Institute should invariably be filled in and submitted. The particulars of this form are as follows. A. General: 1. Sample from: 2. Sent by: 3. Collected on: 4 Source of water: (*a*) Tank or Lake: (*b*) Pipe (from a tap): (*c*) River, stream or channel: (*d*) Spring: (*e*) Cistern or reservoir: (*f*) Well (shallow or deep): 5. Position of source and nature of the soil in which the source is situated, (*a*) gravel, (*b*) sand, (*c*) rock, (*d*) mud and (*e*) clay. 6. Possibility of impurities reaching the water. (*a*) Distance of the source from the nearest habitation, stable or cow shed: (*b*) Distance of the source from cesspools, drains, sewers, etc.: (*c*) Distance of the source from middens, manure heaps: (*d*) Distance of the source from cultivated land, wet or dry cultivation: 7. Meteorological conditions: (*a*) Rainfall, if recent: (*b*) Drought. B. Special: 1. If Pipe: (*a*) Main pipe; (*b*) House pipe; (*c*) When was the pipe last renewed? (*d*) The source of the water conducted by the pipe. Sources: 2. If Tank or Lake (*a*) Supplied by rains, channels, streams or washings: (*b*) Nature of the collecting surface, pervious or impervious: (*c*) Condition of the tank: Built with stones and chunam or mud: (*d*) Presence of any parapet wall preventing washings: (*e*) Nature of the access to animals or men, if any: (*f*) Any watch kept over the tank: 3. If River, Stream or Channel: (*a*) Water perennial or lasting for a short period: (*b*) Floods, common or rare: (*c*) Distance of the nearest place up the stream where any drainage is led into it: (*d*) Nature of the banks of the stream (any existence of burial-ground or cultivation): 4. If Spring; (*a*) Land spring (water through porous soils such as sand, gravel or alluvial earth overlying impervious strata). (Springs in dry rivers should also be included in this.) (*b*) Main spring (water through thick masses of porous rock): (*c*) Intermittent or bournes (usually found in valleys bounded by hills on one side, disappearing during summer); 5. If Cistern or Reservoir: (*a*) Nature of the material with which it is built: (*b*) Open or close; (*c*) Access to men and animals: (*d*) How many times in a year it is cleaned: (*e*) Process of cleaning: (*f*) Original source of water. (Details of this should be entered in its place.) 6. If Well: (*a*) Depth: (Measurements taken some time before will do or else samples should be taken before measurements are taken.) (*b*) Strata through which sunk: (*c*) Nature of the steining: (*d*) Steining, perfect or imperfect: (*e*) Depth to which steining is done: (*f*) Depth of water: (*g*) Open or closed. If closed, nature of material of the covering; (*h*) Any pump attached;

(*i*) Access to men: 7. Signature: 8. Date: 9. Rank: 10. Designation.

Interpretation Of Results Of Quality Tests.

When the report and results of a sample water are unfavourable and differ from your preconceived ideas of the purity of the sample, never attempt to criticise the methods of the laboratory work of the analyst but locate errors, if any, to the right corner, *viz.*: the method of the sampling of water. The bacteriological results of water are judged from the following tentative standards for the Madras Presidency proposed by Major Clemesha, I.M.S. (1909). "Good lake water, less than 100 colonies per cc. on agar at 37° C. No lactose fermenting organisms in 20 cc. No non-resistant organisms in 50 cc. Bacillus lactis ærogenes plentiful. Usable lake water: Less than 200 colonies per cc. in agar at 37° C. No lactose fermenting organisms in 5 cc. No non-resistant organisms in 20 cc. Bacillus lactis ærogenes, very plentiful. Unusable lake water: Bacillus coli found in 1 cc. Fæcal organisms present in proportions similar to those of fresh. Bacillus lactis ærogenes, few or absent. Good river water: Less than 100 colonies per cc. No bacillus coli in 50 cc. Fæcal organisms, not more than 1 in 10 cc. Usable river water: Less than 300 colonies per cc. No bacillus coli in 20 cc. Fæcal organisms, not more than 1 in 1 cc. Unusable river water: 800 colonies per cc. Bacillus coli 1 in 5 cc. Lactose fermenting organisms 10 per cc. Numerous varieties of fæcal organisms. Deep waters: Less than 50 colonies per cc. No bacillus coli in 100 cc. No fæcal bacilli in 20 cc." All filtered water should shew results of the water classed 'good' in the above table. If not, the filter is not doing its work properly and action requires to be taken to put right defects in its working. If tap water results shew deterioration in bacteriological purity from filter effluent, then the conclusion to be drawn is that slime and salt in pipes exist and the pipes need scouring. The chemical results are judged from the following standard table extracted from the 1911 edition of McNally's Sanitary Handbook. "In a good water the various constituents should not exceed these proportions: Total solids should be under 10 parts per 100,000; (*a*) fixed; salts of metals, silica; (*b*) volatile (organic matter, ammonia, nitrites, nitrates) should be under 1·5 parts per 100,000. Chlorine, 1·5 to 3 parts per 100,000. Hardness, total, 30 parts per 100,000 or 21 degrees (Clark's scale). A good soft water contains less than 5 parts per 100,000. Permanent hardness under 3 parts per 100,000. Nitrates; less than 1·5 parts of nitric acid per 100,000. Nitrites, nil. Free ammonia, ·002 to ·005 parts per 100,000. Albumenoid ammonia, ·005 to ·01 parts per 100,000. Sulphates, under 3 parts per 100,000. Phosphates, a trace. Total combined nitrogen (nitrates, nitrites, ammonia), under ·4 parts per 100,000. Oxidisable matter (oxygen absorbed in 15 minutes at 80° F. from potassium permanganate), ·05 to ·1 part per 100,000." In the case of samples of water for proposed water supplies, the interpretation of the results by Local Bodies and engineers is a simple matter for the Director of the Institute invariably pronounces an opinion whether the water from the proposed source is suitable or not for development of a public protected water supply.

Rainfall Statement.

From rainfall statistics which are available for the Presidency, a statement of rainfall for the station nearest the proposed source of supply should be furnished. The following is a specimen of this statement.

Years.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total.
1870	0·30	...	1·10	...	1·05	3·60	4·55	5·90	3·75	8·90	0·75	0·10	30·00
1871	0·40	...	2·00	0·05	1·80	1·25	4·40	2·17	6·95	7·65	12·75	...	39·42
1872	...	...	...	...	8·40	0·30	3·10	9·50	4·50	7·75	11·80	1·90	47·25
1873	...	3·60	...	0·60	0·75	0·40	0·30	8·05	10·30	9·52	1·55	1·45	36·52
1874	...	...	1·10	...	8·85	5·77	5·20	2·30	23·70	11·35	1·15	0·55	59·97
1875	...	...	...	...	3·70	1·90	1·85	8·40	5·05	5·58	0·10	1·10	27·68
1876	...	...	0·45	0·40	1·22	2·15	1·47	2·67	4·57	0·83	0·95	...	14·71
1877	...	...	0·47	0·23	2·01	3·74	0·98	2·04	13·11	9·29	3·18	2·76	37·81
1878	...	...	...	0·38	1·27	4·40	5·57	11·98	8·08	5·55	3·60	1·21	42·04
1879	0·75	3·20	0·89	0·30	4·50	2·16	7·93	2·97	5·08	8·74	1·91	0·45	38·88
1880	0·27	0·65	...	2·36	2·75	0·36	2·65	2·72	4·10	8·35	13·36	2·77	40·34
1881	...	...	...	...	0·58	1·00	0·92	7·43	10·71	3·16	4·58	1·26	29·64
1882	1·10	...	...	0·10	1·37	1·70	3·00	8·01	2·31	2·25	17·76	0·08	37·68
1883	...	...	...	0·35	2·34	3·60	2·87	5·31	5·90	8·73	7·49	4·74	41·33
1884	...	0·05	0·10	...	0·55	1·45	2·95	6·20	5·20	11·62	6·90	9·69	44·71
1885	...	...	...	...	1·45	1·35	2·03	1·32	3·34	5·65	5·08	7·79	28·01
1886	0·07	...	0·35	...	6·72	3·09	4·72	4·58	7·19	5·06	3·34	1·25	36·37
1887	...	...	0·60	...	2·15	7·18	0·35	7·39	4·87	6·81	12·87	6·76	48·98
1888	...	...	...	...	7·11	4·47	3·11	1·23	8·17	11·73	7·50	1·00	44·32
1889	0·60	...	1·00	4·65	...	5·35	6·41	4·10	10·95	7·95	0·36	3·60	44·97
1890	0·09	...	...	3·31	2·85	6·64	4·06	5·62	7·44	9·74	1·55	1·21	42·51
1891	0·60	0·93	...	...	0·65	2·71	0·61	1·52	5·57	6·33	1·33	2·35	22·60
1892	...	0·15	0·15	0·83	1·91	7·57	4·63	7·71	6·61	3·97	1·52	1·16	36·21
1893	0·10	...	2·67	2·20	0·61	4·19	6·61	1·51	0·82	10·94	9·58	...	39·23
1894	0·30	0·44	...	1·06	0·88	1·99	2·85	5·18	5·86	7·06	2·96	1·11	29·69
1895	...	...	...	0·57	1·76	1·42	2·98	3·60	5·64	6·01	0·62	3·85	26·45
1896	0·77	...	...	...	0·82	4·53	0·66	3·94	7·21	1·72	3·91	2·09	25·65
1897	0·36	2·29	...	...	3·08	1·96	3·98	8·66	12·76	5·93	0·33	0·14	39·49
1898	...	0·22	...	1·21	2·70	1·13	1·38	4·41	9·47	4·34	16·45	3·52	44·83
1899	...	...	...	5·24	3·46	0·03	1·21	2·36	10·40	7·35	0·05	0·91	31·01
1900	0·16	...	...	0·83	1·48	2·56	11·34	0·35	5·99	4·49	2·03	1·46	30·74
1901	...	2·51	...	0·04	0·54	2·07	2·87	0·55	4·64	6·71	6·94	5·01	31·88
1902	0·86	0·18	...	0·17	5·33	1·96	1·19	7·00	8·01	6·87	1·87	1·80	35·24
1903	0·55	...	...	...	4·03	4·01	2·58	3·83	15·50	2·92	9·51	6·53	49·46
1904	0·73	...	...	5·24	4·47	0·89	4·33	1·06	4·74	5·52	...	0·20	21·94
1905	0·28	...	1·37	0·22	0·92	1·39	2·36	6·57	3·64	11·60	4·54	0·16	33·05
1906	3·08	...	...	...	0·15	2·27	2·92	11·12	3·64	2·29	1·80	1·81	29·08
1907	...	...	0·96	5·24	1·29	1·48	3·29	0·95	6·45	3·08	5·07	0·74	28·55
1908	...	0·11	...	0·13	1·39	1·46	1·51	0·36	8·75	5·06	0·68	0·24	19·69
1909	5·25	...	...	3·94	6·31	1·15	2·07	14·84	4·88	4·31	0·27	0·07	43·09
Average 1870—1909	0·42	0·36	0·33	0·86	2·58	2·67	3·19	4·88	7·15	6·57	4·70	2·07	35·78
		1·11		3·44			17·89				13·34		

WATER SUPPLY: INSPECTION OF SOURCES OF SUPPLY AND DETERMINATION BY INSPECTION AS TO THEIR SUITABILITY FOR DIETETIC PURPOSES.

Sources Of Supply.

Rain is the primary source of supply. Of the total amount of rain which reaches the surface of the ground, a portion evaporates, a certain quantity flows off the surface and the remaining quantity percolates through the interstices of the soil. The temperature and humidity of the air are the factors which account for the portion of water evaporated from the surface. The permeability of the soil, the slope of the ground and the amount of vegetation are factors which affect the quantity which flows off the surface. When this water is used for water supplies, we store them in tanks as in the case of the towns of Adoni, Vizagapatam, Madras, Ootacamund and Salem, or we utilise the supply from artificial canals as in the towns of Coconada and Kurnool. Natural outlets, such as springs and artificial tappings of the subterranean supply (see fig. 22, plate 150) by means of wells, infiltration galleries, tube wells, and artesian wells are the results of the quantity of rain which percolates into the soil and forms the underground sources of supply. The towns of Vizianagram, Tanjore, Trichinopoly, Madura, Dindigul, Conjeeveram, Nellore, Bezwada, Cuddapah and Gudiyattam are supplied from wells and infiltration galleries. The different sources from which water supplies may be obtained have been classified by the Rivers Pollution Commissioners as 1. spring water, 2. deep well water, 3. upland surface water, 4. stored rain water, 5. surface water from cultivated land, 6. river water to which sewage gains access, and 7. shallow well water. Spring water and deep well water are classed as very palatable wholesome waters. Upland surface water is considered as moderately palatable and wholesome, while stored rain water is moderately palatable and is classed under 'suspicious waters.' Surface water from cultivated land belongs to the class of suspicious and palatable waters. Palatable and dangerous waters are river water to which sewage gains access and shallow well water. In this Presidency water is dra n from the following sources for a town water supply: 1. The subsoil water of a river. 2. The surface water stored in storage tanks from canals. 3. Tanks. 4. Infiltration galleries and wells in sandy strata outside the river beds. 5. Wells and springs.

Suitability For Development Of Water Supplies.

In the case of tank water supplies, the areas the drainage of which forms the source of supply to the tank are called 'catchment areas' 'gathering grounds,' or 'upland surfaces.' The geological formation and surface conditions of catchment areas from which the water is collected affect the character of water in the tanks. Marshy ground, as it holds the product of decay and numerous insects and animalcula, and peaty land, as the water of which contains acids (humic and ulmic) due to decomposition of vegetable matter in the absence of oxygen, are not suitable gathering grounds. It is not possible to find a gathering area which is altogether free from possibility of some sort of contamination. In the case of a catchment area of a drinking water supply tank, the following sanitary points should receive attention: 1. The area should, if possible, be fenced in by an impassable fence, but in any case the area should be strictly conserved and supervised. 2. No habitations within the area should be allowed. 3. No cultivation of the land should be permitted. 4. The supply channel to the tank from the catchment area should be frequently inspected and kept clear. In the case of water supply works consisting of infiltration galleries or wells in the beds of rivers, it is usual to select a site above which there are no villages for a distance of $1\frac{1}{2}$ miles (preferably 3 miles) as a minimum, as it is usually impossible to find a site with no villages above the point of draw off. There are instances of sites of galleries in which villages within one and half miles exist. In these cases, provision is made to divert the drainage from these villages to discharge at a point on the down stream side beyond a minimum distance of half a mile. There should be no burning or burial grounds especially the latter for a distance of 3 miles on the up stream side and for a distance of half a mile on the down stream side. In the case of canal water supplies, the site selected for the tanks to store water to tide over the periods when the canal is closed should have no burial or burning grounds for a radius of half a mile and should not receive the drainage of surrounding areas. The site should further be suitable for the location of the storage tank and other head works from an engineering point of view. The requirements for sites of wells will be discussed under wells in a subsequent lecture.

WATER SUPPLY: METHODS OF FILTERING AND PURIFYING SMALL QUANTITIES OF WATER AND OF OTHERWISE RENDERING IT SAFE FOR DOMESTIC USE.

Sand Filters.

There is no doubt that it is impossible to obtain a filtrate from sand or other filters which will satisfy ideal conditions or opinions of some medical experts. The object aimed at is not to satisfy the above condition but it is to obtain a class of water which is good for drinking purposes. Tank waters, surface waters from canals and perennial rivers require to be treated on filters before they can be distributed in the town. In the present day, sand filters and mechanical filters are the two classes of filters generally adopted. The sand filters are usually of type shown on plate 185 and consist of cisterns in which are laid filtering materials. The filtering materials take up a depth of 5 feet. Over the top of the filtering materials, the depth of water in the filters is usually 3 feet. In an appendix are given the methods of starting and working these sand filter beds. I may, however, here state 1. that the area of filter beds is determined on the basis of one square yard per 450 gallons to be filtered in a day of 24 hours; and 2. that one of the beds should be in reserve. In some books, it is stated that the area to be provided is on the basis of 600 to 700 gallons, but experience in Madras has shown that this rate should not exceed 450 gallons per square yard. It would be advantageous if the rate is limited to 400 gallons per square yard. If two beds are provided, one should be in use, the other in reserve; similarly if three are adopted, two should be in use and one in reserve. As a rule, 4 beds are provided, the area of three beds being sufficient for town requirements while the fourth is always kept in reserve.

Mechanical Filters.

There is no doubt as to the efficiency of the more generally adopted slow sand-filtration process as extensively employed for large supplies where it is carried out under careful supervision and control. With lack of supervision and control, efficiency in the purity of water after passing it through sand filters is of course impossible. The mechanical filtration of water for purposes of public supply has been practised for many years past in America and in Europe, but it is only now that we are beginning to introduce this method of purification in India. There are various types of mechanical filters in use, for example, 1. those depending on straining action only; 2. those combining coagulation and subsidence with straining worked either as gravity filters or under pressure; and 3, those utilising the oxidising effect of the imprisoned air by pumping in water under pressure and then taking out suspended impurities by mechanical straining. As types of mechanical filters may be mentioned the Jewell Filter, the Paterson's Filter, and Mather and Platt's Filter, the Bell Filter and the Candy Filter. In the Jewell system, a coagulant is added to the water before it passes to the filter. The coagulant is usually sulphate of alumina. After the addition of the coagulant the water is allowed to move (very slowly) through settling tanks in which deposition of suspended particles takes place, the bacteria being at the same time reduced by from 40 to 70 per cent. The water passes from the settling tanks into the filtering sand which is contained in cylindrical drums. The sand is about four feet in depth. The presence of the coagulant in the water causes the formation of a gelatinous film, on the surface of the sand, through which water is forced at a rate of 2,000 to 3,000 gallons per square foot of surface in 24 hours. The leading features of the Jewell filter are: the negative head, the screen system, the uniform rate of flow and automatic control of the water level over the filter bed, and the rate of filtration, a weir around the filter tank for the removal of the dirty wash water, and the arrangement of valves by which the working of the filters is controlled. The rapidity of flow is obtained by use of a considerable head of water, 6 to 14 feet, of which, however, only two feet are above the sand, the remainder being represented by negative head. The Paterson Filter and the Bell Filter are on much the same principle as the Jewell Filter. The Bell Filter is a very useful filter for the purpose of removing sedimentary matter but its efficacy is not so great as regards micro-organisms as is the case with the Jewell and the Paterson types. Mather and Platt's pressure filters consist of closed cylindrical tanks, with sloping sides and domed top and bottom, supported on four cast iron legs. An annular channel through which the unfiltered water enters from the inlet valve is fitted at the upper part of the cylinder. This channel also serves the purpose of carrying off the dirty water when the filter is cleaned by reversing the direction of flow. The filtering

material consists of quartz crystals in graded layers with the finest at the top. The Candy Filter consists of steel cylinders into the upper part of which water is pumped under pressure and filtered downwards through about 5 feet of sand and gravel with which are combined a material of a depth of 2 feet in the thickness, called 'oxidium'. These filters are considered specially suitable for waters containing iron in solution or suspension.

Domestic Filters.

It is unnecessary to refer here to the old system of sand and charcoal chatty filters as it is now some years since this method has been given up on sanitary grounds. Of the present domestic filters now in use may be mentioned: 1. The Berkfeld and 2. the Pasteur (Chamberland) filters. The objects for which domestic filters are employed are: 1. for removing visible suspended matter, 2. for arresting bacteria, and 3. for modifying the chemical composition of the water itself. From a sanitary standpoint, it is of no practical use to consider the effect of a filter on the chemical composition of a natural water. There is no practical evidence to show that the chemical treatment by a domestic filter has produced any modification in the original water to consider the filtrate more wholesome or less dangerous than the same water before it had undergone such chemical treatment. Practically speaking, few domestic filters do more than remove suspended matter. As regards the arresting of bacteria, it may be said that the passage of bacteria through the pores is not caused by mere pressure of water but is probably due to the growth of bacteria in the pores of the filter under the influence of substances favourable to their development. The nature of the bacteria also influences to a considerable extent their growth. Too much reliance should not be placed on the efficacy of domestic filters. It may however be stated that the Pasteur filters have been tested under conditions permitting accurate record with the result that they are efficient in arresting pathogenic bacteria contained in drinking water. Whenever domestic filters are employed, care should be taken to brush off the suspended matter accumulated on the surfaces of the filtering materials and to sterilise the filtering medium every third or fourth day. The best and the most reliable procedure to ensure safety of drinking water by any individual is to sterilise it by means of heat, the water being afterwards allowed to cool by natural means.

Design For A Scour Pipe: Plate 183.

In the above plate is illustrated the type design No. 135 issued with proceedings of the Madras Sanitary Board No. 528-S., dated 23-9-12 and No. 270-S., dated 23-4-13. The specification report which accompanied this design was as follows: The results of analyses of the pipe distribution system of existing water works show in many cases the necessity for thorough and systematic scouring of the distribution lines. 2. The scour pipe arrangements required are shown in the type design. 3. The scouring should generally be done at times of greatest pressure, that is, during the night or period when least water is drawn; the pumping plant, if any, being specially worked for this purpose. 4. The intervals between periods of scouring should not exceed 10 days. 5. The T scour pipe being laid vertically downwards and the discharge end being above ground will result in efficient scouring action, and will also prevent foul air and matter being in-sucked into the mains. 6. The pipes and fittings are of the usual types and call for no remarks. 7. In cases where the scour is discharged into existing street ditch side drain, the drain should be pitched with stone for a distance of 10 feet on either side of point of discharge. 8. The diameter of scour branch should be half diameter of main pipe plus one inch subject to a minimum diameter of three inches.

WATER SUPPLY: CONSTRUCTION OF WELLS, TANKS, TUBE WELLS AND BORINGS; THE PROPER CONSTRUCTION OF WELLS TO PREVENT THE INLET OF SURFACE WATER; THE CALCULATION OF THE CAPACITY OF A WELL AND THE AVERAGE SUPPLY OF WATER LIKELY TO BE OBTAINED FROM IT; THE METHOD OF DRIVING TUBE WELLS, THEIR USE AND THE POSITION IN WHICH SUITABLE; CALCULATION OF CAPACITIES; CONSTRUCTION OF SMALL CISTERNS AND TANKS FOR STORAGE OF WATER.

Wells.

There are usually three classes of wells, *viz.*, 1. shallow well, 2. deep well, 3. artesian well, which is simply a variety of a deep well. In fig. 22, plate 150, is given a diagram showing ground water, deep water, spring, stream and different kinds of wells. Wells sunk into superficial beds of sand or other permeable stratum are called shallow wells. In many villages, shallow wells are the usual sources of supply. They are frequently polluted with sewage in the most disgusting manner and by the manuring of the land. Water of a shallow well being clear, sparkling, and very palatable, is no indication that the water does not possess dangerous properties. The water of a well is considered by the general public as safe water because it is 'well water.' The fact that the water during its passage of a few feet of a porous soil is freed of suspended matters but not its dangerous properties is not understood by most people. Where a shallow well is to be used as a source of supply, the following measures should invariably be adopted: 1. Up to summer water level, there should be a filling of broken stone or gravel to a width of 2 feet all round the steining, the top six inch layer of these being half inch size. 2. The steining above this should be filled all round with clay puddle to a width of two feet. 3. The clay puddling should be continued below the platform for the entire width of the excavation of the well so as to form an impervious stratum with the object of preventing direct access of surface water into the well without passing through the natural ground. 4. There should be a platform at least 6 feet wide all round the well and a surrounding drain with a leading off drain at least 150 feet in length. 5. The inside of the steining and the exposed faces of the platform, parapet wall, drain, etc., above ground level should be plastered with cement. On a reference to fig. 22, plate 150, it will be observed that A is a superficial bed of pervious sand or gravel; B is ground water emerging at L as a spring, which finds its way to the stream M; CC is an impervious bed or stratum of clay; DD is a deep pervious bed of limestone or sand stone, forming in its lower part a large subterranean sheet or reservoir of water, EE, the level of which is O,O,O,O; FF is an impervious formation of solid rock supporting the mass of water, E, in the pervious bed, D; GG' is a seam of gravel traversing the bed of clay C, receiving the surface drainage at G, and giving rise in wet weather to a so-called land spring at G'; H is a house with privy and cess-pit which may pollute the ground-water B; I is a surface-well sunk into the ground water B; K is a deep well steined as far as the clay so as to exclude the ground water, and tapping the subterranean water E; N is an artesian well, in which, the mouth being below the line O, O, O, O, the water rises under pressure in the form of a natural fountain, requiring no pump as all the others do; P is a deep well steined to exclude the land spring in GG'; Q is a well which, though drawing from the same source, and at the same depth as P, is technically a surface well, since it does not pass through any impermeable stratum. In determining the question of site for a well, the chief factor is the direction of flow of the ground water. If the ground water becomes polluted by the existence of a cesspool or drain close by as shown at H, the water in the well will naturally acquire dangerous properties. The risks of such pollution are always greatest after heavy rainfalls when the level of the ground water is high and more likely to be brought into immediate contact with surface polluted water. The extent of influence depends upon pumping as shown in fig. 25, plate 151. On a perusal of this figure, it will be seen that while the rest level was EE and when the water is depressed from A to B, the influence will be communicated in all directions from the site as shown by the circles EE and C D depending upon the porosity or permeability of the surrounding strata. The lines

EDB and ECB are termed the lines of depression of ground water. The length A E or the extent of the influence of pumping is usually expressed in the terms of the head of depression AB in figure. Sometimes the extent of influence is as much as 160 times the depth of depression. In cases where the surface flow is to be conserved, it is usual to provide a puddle wall as shown in fig. 24, plate 150. Where the well is provided with hand pumps it would be better to cover the well as shown in plates 153, 154 and 155. However, if objection is taken to cover the well, it would be advantageous to extend the height of the steining above ground level to seven feet as shown in plate 156.

Examining Wells.

In the examination of a well, the following points should receive attention: 1. Evidences, if any, of liquids finding their way through the steining. 2. The position of the pump and rising main. 3. The depth of water. 4. The distance of the water level from the ground surface. 5. The depression caused by pumping and the time that elapses before the original water level is restored after pumping ceases. 6. The surroundings and the distances from possible sources of pollution. 7. The nature and dip of the soil and subsoil. 8. The condition of the ground immediately round the well. 9. The method of disposal of waste water from the pump.

Yield Of Wells.

There are two methods of testing the yield of wells, *viz.*, 1. Discharge test and 2. Recoupment test. In the former, the water in well is kept at a constant head and the quantity discharged by continuous pumping at the constant head is ascertained. The yield at different heads may thus be ascertained. This is not as reliable as the recoupment test. The recoupment test consists in lowering the level of water in well, dry or to considerable depths, by pumping and noting the rise of water in well at intervals of 15 or 30 minutes. It is essential for accuracy that the yield recoupment tests are carried out after a long drought, and the depression of water by pumping before recording the recoupments is considerable. The observations are recorded in statements as under :

Specimen Of Yield Test Of A Well.

Normal summer water level = 11·26. Inside diameter of well = 10 feet.

Date.	Hour.	Water level in well.	Interval in minutes.	Depression of water level in well. Feet.	Depression of water level in well. Inches.	Head of water in feet.	Quantity discharged during the interval in gallons.	Quantity of water in well in gallons.	Estimated net quantity of inflow in gallons. During the interval.	Estimated net quantity of inflow in gallons. Per minute.	Remarks.
1	2	3	4	5	6	7	8	9	10	11	12
March. 07	A. M.	A									
28	6	11·26	...	...	...	...	...	...	...	...	At head of 1·79 feet, the discharge of pump equalled inflow.
	6-30	10·93	30	·33	4	·33	324	163·36	160·64	5·35	
	7	10·59	30	·34	4	·67	356	163·36	192·64	6·42	
	7-30	10·30	30	·29	3½	·96	380	142·94	237·06	7·90	
	8	10·09	30	·21	2½	1·17	400	102·10	297·90	9·93	
	8-30	9·91	30	·18	2¼	1·35	400	91·89	308·11	10·27	
	9	9·74	30	·17	2	1·52	412	81·68	330·32	11·01	
	9-30	9·59	30	·15	1¾	1·67	404	71·47	332·53	11·08	
	10	9·47	30	·12	1½	1·79	396	61·26	334·74	11·16	
	12 Noon.	9·47	120	...	...	1·79	1,320	...	1,320	11	
	A. M.	B.									
29	6	11·24	...	...	...	...	...	...	...	...	At head of 1·77 feet, the discharge of pump equalled inflow.
	6-30	10·95	30	·29	3½	·29	308	142·94	165·06	5·50	
	7	10·66	30	·29	3½	·58	348	142·94	205·06	6·83	
	7-30	10·41	30	·25	3	·83	356	122·52	233·48	7·78	
	8	10·18	30	·23	2¾	1·06	360	112·31	247·69	8·25	
	8-30	9·97	30	·21	2½	1·27	416	102·10	313·90	10·46	
	9	9·78	30	·19	2¼	1·46	424	91·89	332·11	11·07	
	9-30	9·62	30	·16	2	1·62	412	81·68	330·32	11·01	
	10	9·47	30	·15	1¾	1·77	404	71·47	332·53	11·08	
	12 Noon.	9·47	120	...	...	1·77	1,320	...	1,320	11	
	A. M.	C.									
30	6	10·93	...	...	...	...	...	...	...	...	At head of 1·46 feet, the discharge of pump equalled inflow.
	6-30	10·68	30	·25	3	·25	260	122·52	137·48	4·58	
	7	10·43	30	·25	3	·50	280	122·52	157·48	5·24	
	7-30	10·22	30	·21	2½	·71	308	102·10	205·90	6·86	
	8	10·03	30	·19	2¼	·90	324	91·89	232·11	7·73	
	8-30	9·87	30	·16	2	1·06	332	81·68	250·32	8·34	
	9	9·72	30	·15	1¾	1·21	388	71·47	316·53	10·55	
	9-30	9·60	30	·12	1½	1·33	396	61·26	334·74	11·15	
	10	9·47	30	·13	1½	1·46	396	61·26	334·74	11·15	
	12 Noon.	9·47	120	...	...	1·46	1,320	...	1,320	11	

Note: —Head of water in feet, Col. 7, is the difference between water levels A, B and C and level of water at end of each period of observation, Col. 3. To ascertain the quantity of water in a well, take half the circumference (in the clear) and multiply by half the diameter; multiply the result by the depth, which gives the cubic measure; then reckon 6 gallons and 1 pint to the foot cube.

Specimen Of Recoupment Test Of A Well.

Normal summer water level = 11·26. Inside diameter of well = 10 feet.

Date.	Hour.	Water level.	Interval in minutes.	Head of water in feet.	Rise of water in well. Feet.	Rise of water in well. Inches.	Supply in gallons during the interval.	Supply in gallons per minute.
1	2	3	4	5	6	7	8	9
28th March 1907	12 Noon	9·47	...	...	...	...	...	...
28th "	12-15 p.m.	9·80	15	1·79	·33	4	163·3632	10·89
28th "	12-30 "	10·14	15	1·46	·34	4	163·3632	10·89
28th "	12-45 "	10·43	15	1·12	·29	3½	142·9428	9·53
28th "	1 "	10·64	15	·83	·21	2½	102·1020	6·81
28th "	1-15 "	10·82	15	·62	·18	2¼	91·8918	6·13
28th "	1-30 "	10·99	15	·44	·17	2	81·6816	5·45
28th "	1-45 "	11·14	15	·27	·15	1¾	71·4714	4·76
		A						
28th "	2 "	11·26	15	·12	·12	1½	61·2612	4·08
29th "	12 Noon	9·47	...	...	...	...	...	...
29th "	12-15 p.m.	9·76	15	1·77	·29	3½	142·9428	9·53
29th "	12-30 "	10·05	15	1·48	·29	3½	142·9428	9·53
29th "	12-45 "	10·30	15	1·19	·25	3	122·5224	8·17
29th "	1 "	10·53	15	·94	·23	2¾	112·3122	7·49
29th "	1-15 "	10·74	15	·71	·21	2½	102·1020	6·81
29th "	1-30 "	10·93	15	·50	·19	2¼	91·8918	6·13
29th "	1-45 "	11·09	15	·31	·16	2	81·6816	5·45
		B						
29th "	2 "	11·24	15	·15	·15	1¾	71 4714	4·76
30th "	12 Noon	9·47	...	...	...	...	...	...
30th "	12-15 p.m.	9·72	15	1·46	·25	3	122·5224	8·17
30th "	12-30 "	9·97	15	1·21	·25	3	122·5224	8·17
30th "	12 45 "	10·18	15	0·96	·21	2½	102·1020	6·81
30th "	1 "	10·37	15	0 75	·19	2¼	91·8918	6·13
30th "	1-15 "	10·53	15	0·56	·16	2	81·6816	5·45
30th "	1-30 "	10·68	15	0·40	·15	1¾	71·4714	4·76
30th "	1-45 "	10·80	15	0·25	·12	1½	61·2612	4 08
		C						
30th "	2 "	10·93	15	0·13	·13	1½	61·2612	4·08

Note :—Head of water, column 5, is the difference between water levels A, B, C, and water levels at end of each period of observation, col. 3.

Well Water Supply Arrangements : Plates 153, 154 And 155.

In the above plates are illustrated the type designs Nos. 137, 138 and 139 issued with proceedings of the Madras Sanitary Board No. 554-S., dated 7th October 1912. The specification report which accompanied these designs was as follows : 1. The wells shown in the designs are roughly estimated to cost Rs. 1,700 to Rs. 2,300 (plate 153), Rs. 2,200 to Rs. 2,800 (plate 154) and Rs. 10,000 (plate 155). 2. It will be of considerable assistance to those who intend to construct wells if a description is given of the actual operations required and if special attention is drawn to the more important points. 3. The type-designs illustrate two methods of constructing wells. 4. Site : The site of a well should be selected bearing in mind the following important points : (1) The site should be as suitable for access as the expected supply of water and the state of the surroundings permit. (2) There should be no stagnant pool of sullage, drain, or other permanent means of contamination, within 300 feet of the site proposed. Built wells : 5. Excavation : The left hand illustration is a cross section of what is called a built well, and in constructing this well the first thing to be done is to make an excavation down to the level which is at least 10 feet lower than the summer water level as disclosed by the result of a boring or by the operation of excavation itself. The cross section of the well in the type design shows a standard size of stepping of excavation but the actual form this stepping will take can only be judged from the behaviour of the soil at the site of the well during construction. 6. Borings : It may with advantage be remarked here, that for all wells of any importance it is better to put down a boring at the proposed site, before drawing up a proposal for sanction for the construction of a well. This boring besides giving reliable information as to the nature of the soil that will be met with during the excavation, thus enabling an estimate to be accurately prepared, also gives the even more important data as to the depth, quality, and quantity of water likely to be available at the proposed site of the well. The preliminary putting down of a boring should therefore, as a general rule, precede the submission of proposals for construction. Only in those cases where the site of the proposed well is surrounded by old wells, which yield a satisfactory supply, should the preliminary putting down of a boring not be insisted on. The excavation having been carried out to summer water level, the further deepening of the excavation should be done, the water met with being bailed out using chatties, picottahs or steam or hand pumps as may be found necessary. 7. Steining : The steining of a well is the masonry lining to the excavation and is required to prevent the sides of the excavation slipping in. The steining usually takes the form of concentric and radial lines of brick or stone masonry courses, the circular form of steining being adopted not only to avoid corners but principally because this form is usually cheaper than any other. The steining of the well is then built up, the first portion from the bottom of the well to summer water level being constructed of dry stone or brick in clay, or masonry in mortar, with a sufficient number of weep holes, as may be decided on. The space left between the steining and the excavation should be filled in with broken stone or pebbles the top six inch layer of these being half inch size. The remainder of the steining should be built in masonry in mortar as per type design. The filling in behind the steining should be carefully carried out, as the building of the steining proceeds, of materials shown in the type design, and special care should be taken that the clay puddle backing to the steining is actually done, the first part being placed on the top of the small stone backing and the rest against the outside of the vertical steining. 8. As soon as the earth filling is completed the clay puddle layer underneath the platform should be placed in position, all layers of clay puddle being bonded into each other so as to form an impervious stratum and thus prevent direct access of surface water into the well without first passing through the natural ground. 9. The platform should be constructed at least 6 feet wide as shown in the design and a surrounding drain with a leading off drain at least 150 feet in length should be provided. The inside of the steining should be plastered with cement, in all cases where the nature of the steining permits which will be in the case of all wells constructed of brickwork. This plastering should extend the whole depth of the well steining as far as lowest summer water level. In the case of steining constructed of rough stone, the joints should be pointed with cement down to summer water level when it is found impracticable to plaster this type of steining. 10. Sunk well : A "sunk well" is used where the soil or sand at the site is easily removed by well sinkers. A "built well" is constructed at those places where hard or stiff soil exists which would resist the use of a "sunk well." The first operation in constructing a sunk well is to make an excavation to summer water level. 11. Curb : A wooden curb is then made of three-inch planks in three layers and of a form slightly larger in diameter, about 2 inches, than the well to be constructed. The three-inch planks are used of different widths as shown in the type design and are nailed together so as to break joint. An angle iron with edge downwards, and of circular shape slightly larger than the diameter of the curb, is then

fastened to the lower plank of the wooden curb so as to form a cutting edge. Holding down bolts, ¾ inch in diameter and about six feet long, are then bolted to the centre of the wooden curbs, the number of bolts being determined by the circumference of the curb and the spacing of the bolts which will be 4 feet apart. 12. Steining: The curb is then placed in position at summer water level and the masonry to a height of 6 feet is then built and left to set. The requisite number of weep holes, that is to say, every 4 feet horizontal and one foot vertical distance apart, is provided when the lower portion of the steining is constructed of masonry in lime or cement mortar. After the masonry is set, bar iron washer plates with suitable holes are placed over the holding down bolts and screwed tight in position by the use of nuts. The soil inside the well and under the curb is then scooped out by well sinkers who use bailing baskets or other local means of excavating the soil. The soil being scooped out from under the curb, equally on all sides, the well steining is gradually sunk to a depth of nearly six feet. More steining is then built on the first ring and left to set and the well sinking is continued until the requisite depth is attained. The steining is then completed, the clay puddle backing being carefully put in place with the remainder of the earth filling and the platform, leading off drain, and cement plastering completed as in the case of the built well. The platforms and parapets and inside surface of steining are preferably plastered with cement so as to provide a smooth and impervious coating: Type design for well with hand pumps: 13. A sanitary improvement on the pulley and bucket arrangement of the ordinary type of well is the provision of two or more hand pumps such as the semi-rotary type of the 1½ inch suction pipe size. There might either be 2, 3 or 4 of these pumps of which only one should be used at one time, the others being locked with a key, to be in the charge of the Union Chairman, so that when a pump gets out of order another can be quickly brought into use while the first is under repair. 14. Those who desire to take water from a well would work the handle of the semi-rotary pump, backwards and forwards, and thus fill the brass or earthenware chatty with water which would then be free from the usual contamination caused by the bucket and rope. In the case of a well fitted with pulley arrangements, ropes and buckets, the disturbance of the water in the well by the dashing of the buckets into it will prevent the breeding of mosquitoes or actually destroy the larvæ. In the case of the well fitted with pumps, the water in the well will be in a quiescent state as it will not be disturbed by the operation of pumping and consequently the breeding of mosquitoes will not be prevented as in the case of the bucket well. 15. It is therefore necessary to devise some means of covering the top of a well so as to prevent not only contamination from outside but also the breeding of mosquitoes. The provision of wire gauze of fine mesh is not considered a suitable covering for a public well as the gauze is liable to be broken and left in a state of disrepair thus defeating the object of its provision. It is considered that the public wells should be permanently covered as they will require opening only at long intervals of time. A design has therefore been drawn up for a public well to be fitted with hand pumps either 2, 3 or 4 in number according to the importance of the well. The well steining is built up to a height of 7 feet above ground to prevent people squatting on the covering, which they would do if it was at any lower level, and to make it inconvenient for any one to climb up and sit on the covering. The well is roofed with an ordinary terrace roof, the joist being small rolled steel or metre gauge flanged rails. 16. Provision is made for a manhole cover consisting of a ¼ inch iron plate bolted to the terrace. The bolts will be lewis bolts cemented into the roof. A clear opening of 2′ 3″ is provided as shown in the design. Ventilation of the well is not provided as there are objections to its provision. Wire gauze ventilators, if provided, would defeat the object of the covering. 17. The cost of each well varies with its dimensions and with local circumstances. It may however be stated that the cost of each semi-rotary pump fitted complete on a well as shown in the type design will be about Rs. 30. Type design for wells for the larger unions: 18. This type design shows instead of semi-rotary pumps, a strong hand pump to be worked by Union coolies so as to fill two iron tanks each of dimensions 4′×4′×4.′ The capacity of each tank is 400 gallons and as the two tanks are connected by a pipe the combined capacity will be 800 gallons. Each tank is provided with a tap so that water can be drawn from the tanks without the remainder being contaminated. Each tank is also provided with a locked-up manhole cover and a scour valve for cleaning purposes. 19. The top of the well is covered over so as to avoid contamination of the water, prevent the breeding of mosquitoes in the still water, and prevent abstraction of water by the use of dirty ropes and buckets. 20. The tanks and the pumps are placed on a suitable cemented platform provided with a leading off drain 150 feet long so that no stagnation of spill water will occur near the well. 21. The cost of a suitable pump and two iron tanks each of 400 gallons capacity provided with ½ inch brass taps will be about Rs. 800, in addition to the cost of the well, platform and leading off drain. Type design for well provided with a pump, reservoir and distribution pipes and fountains: 22. In this design a hand pump to be worked by Union coolies is

provided so as to pump water into an elevated reservoir, whence it will be distributed throughout the Union by means of cast iron distribution pipes and fountains. The arrangement is shown in the plan which shows a masonry elevated reservoir, but iron tanks supported on pillars may be substituted, for local reasons, if considered advisable. 23. The cost of an ordinary well as shown in the type design, a hand driven pump, an elevated masonry reservoir, and one mile of distribution pipes and 4 fountains may be taken as approximately Rs. 10,000. 24. When the quantity of water to be lifted by the pump exceeds 30 gallons per minute and the lift exceeds 40 feet, a small oil engine driving a centrifugal or a plunger pump should be substituted for the hand pump shown in the type design. 25. Upkeep of wells: The upkeep of all wells should be carefully and strictly attended to. (1) All leaves and other floating matter which gather on the surface of water in an open well should be carefully removed immediately they are observed, and for this purpose public wells should be periodically inspected by responsible officials. (2) Semi-annually the inside surface of the steining of all open public wells above lowest water level should be lime-washed using for the purpose burnt lime freshly slaked at the well site. (3) Cracks which may appear in the masonry subsequent to construction and prior to the semi-annual lime washing should be filled up with cement mortar or cement grout. (4) When a pump gets out of order, a spare pump should be immediately unlocked for use and the former repaired by a competent fitter without delay. To enable this to be done, spare rubber washers, valves and nuts should be kept in stock by the Union Chairman.

Arrangement Of Fixing A Hand Power Pumping Plant On One Side Of A Well: Plate 152.

In the above plate is illustrated the design of a well to which is installed a kite motion railway pattern pump in a separate chamber built on one side of a well. As the summer water level in this case is 24 feet below ground, the pump barrel is placed in a pit by the side of the well so that the suction is not more than 20 ft.

An Open Well With One Inch Semi-Rotary Pumps: Plate 156.

In the above plate is illustrated the type design No. 144 issued with proceedings of the Madras Sanitary Board, No. 413-S., dated 26-6-1913. The specification report which accompanied this design was as follows: The well is shown open and the parapet wall is shown built to a height of 7 feet above platform level to prevent easy access to the well and so prevent contamination. An open well of this description might be built in places where the site was removed from roads, buildings and other sources of contamination and in the future, if then considered necessary, the well could be covered at a small cost. In the drawing, four metre gauge rails are shown close to the suction pipe to permit of easy access to the suction pipes of the pumps for repairs to the foot valves. Wrought iron steps inside the steining of the well are provided for access to the rails. The semi-rotary pumps are now shown in complete detail with measurements carefully checked from the sample well at the Sanitary Engineer's office. The cost of a new well similar to that shown in the drawing, at Madras rates, will be Rs. 1,500. Four one inch semi-rotary pumps are shown attached to the well; of these only three will be in use at one time and the fourth will be a spare pump in reserve. For this purpose the handle of the pump not in use should be removed and kept in the custody of the Union Chairman. Specification for a semi-rotary hand-pump, one inch suction and one inch delivery. Pump casing: To be of cast iron and provided with two flange connections. Each connection to have a spare flange, provided with rubber insertion washer, bolted to the corresponding flange and screwed for 1" galvanised pipe. The casing to have two lugs to enable the pump to be bolted to the parapet wall of a well, as shown in the plan. The diaphragm, the valve boxes and the valves to be of brass. The pins for keeping the valves in correct position to be also of brass. The annular space in the valve boxes is usually filled with leather so as to obtain a water-tight fit between the boss of the diaphragm and the valve boxes. This space should be filled with fibre, vulcanised rubber or other efficient hard wearing material instead of the leather, which for religious reasons, is undesirable. Spindle and handle: The spindle to be of mild steel, the outside end being tapered on four sides and screwed to receive a handle. The tapered portion of the spindle and the boss of the handle to be of sufficient length to ensure a firm hold before the nuts are put on the screwed part of the spindle. The handle to be of iron as shown in the plan and covered with tough wood. The wood covering should be in one piece. The wooden casing should be of tough and durable wood such as beech or teak. The end of iron handle to be provided with a small washer and riveted over to prevent the wooden casing slipping off the iron core. The handle to be 15" in length measured from the centre of the hole to receive the spindle. The hole in the boss of the handle to be square tapered and to accurately fit the tapered end of the spindle. The end of the spindle to be screwed to receive a nut and a check nut. Each pump to be complete with galvanised wrought iron

suction piping, foot valve and strainer and a small length of discharge pipe as shown in the plan accompanying this specification. The vertical length of straight suction pipe from bend to foot valve to be 22 feet. The distance between the steining and the suction pipe to be 6 inches. Each pump should be supplied with two long bolts with requisite nuts and an iron plate inside steining should be supplied with each pump as shown in the plan. General remarks: The following remarks should receive consideration. The pumps are intended to be used in large numbers on village wells and the facilities for repairs will be few. It is therefore preferable that every opportunity should be taken in the manufacture of this type of pump to ensure at a reasonable cost the hard wearing qualities necessary if frequent repairs and renewals are to be avoided. The following suggestions are made for the consideration of the makers: Should the usual leather or fibre joint for water-tight purposes between the boss of the diaphragm and the valve box be made of anti-friction metal? Should there be similar anti-friction pieces at the ends of the diaphragm to permit of the renewal of a water-tight bearing and avoid the replacement of the diaphragm required as at present? Spare parts: The following spare parts will be required in the proportion of 10 per cent. of the number of pumps ordered: (1) Valve boxes with valves, pins, and studs, complete. (2) Diaphragms with spindles, glands and nuts. (3) Handles with nuts and check nuts. (4) Rubber washers for joints for flanges and cover for casing. (5) Bolts and nuts for flanges.

List of fitter's tools.

	£	s.	d.
1 box fitter's tools (containing suitable tools for the repair of semi-rotary and other pumps at the District head-quarter workshop)... ...	5	0	0
1 standing vice (width of jaw 4″) fitted to small portable bench made of wrought iron parts	2	10	0
Note: Wrought iron or mild steel preferred as cast iron bench is more easily broken.			
2 bench vices (width of jaw 4″) ...	2	12	0
2 pipe vices for tubes ¼″ to 2″ ...	1	5	0
1 chain pipe wrench to take piping ¼″ to 2½″	0	12	6
3 combined pipe wrenches and cutters to take piping ¼″ to 1″ with three spare cutters for each wrench ...	2	0	0
2 combined pipe wrenches and cutters to take piping 1¼″ to 2″ with three spare cutters for each	1	15	0
1 set taps and dies for screwing galvanised piping ¾″, 1″, 1¼″, 1½″ and 2″ in box, complete	6	0	0
1 set taps and dies Whitworth standard for screwing bolts and nuts ¼″ to 1″, in box, complete	4	10	0
2 one foot steel rules for fitters, 1½″ wide..	0	3	0
1 small box fitter's tools containing, say, 24 suitable tools for executing small repairs to pumps at some distance from head-quarter workshop ...	2	5	0
Note: This box will be carried in a pony or trotting bullock cart.			
Total ...	28	12	6

Abstract Of Quantities For An Open Well With One Inch Semi-Rotary Pumps: Plate 156.

Quantity.	Description of work.
4,165 c. ft. ...	Earthwork, excavation and filling in.
1,829 " ...	Clay puddling.
596 " ...	Brickwork in chunam with weep holes every 4′ horizontal 2 feet vertical distances.
1,029 " ...	Brickwork in chunam.
102 " ...	Concrete in chunam.
1,594 sq. ft. ...	Plastering with cement, ½″ thick, (1 : 3).
6 c. ft. ...	Cutstone work.
No. 4 ...	Wrought-iron steps.
24 r. ft. ...	S. I. Railway old rails.
12 " ...	Sinking 10 feet well.
No. 1 ...	Well curb for a 10 ft. diameter well made up of 3″ planks in layers and of a form slightly larger in diameter, about 2″, than the well including angle iron cutting edge, ⅝″ holding down bolts, 6 feet high, etc., complete.
No. 4 ...	1″ semi-rotary pumps with bends, 1″ wrought-iron tubes for suction, foot valve, etc., including fixing complete.
150 r. ft. ...	6″ leading off drain.
	Bailing or pumping during sinking.
	Unforeseen works, 5 per cent.
	Contingencies, 5 per cent.
	Petty supervision, 2½ per cent.
	Total Rs...

A Deep Well With Pump And Iron Tank With Taps Or Masonry Reservoir With Taps: Plate 157.

In the above plate is illustrated the type design No. 145 issued with proceedings of the Madras Sanitary Board, No. 413-S., dated 26-6-1913. Deep and shallow wells: When the depth of lowest summer water level in a well is more than 20 feet below the platform level, the well should be considered a deep well and provision should be made for placing the pump barrels of a

pump below ground so that the total length of suction will not in the case of double barrelled kite motion railway pattern pumps be more than 22 feet measured from the foot valve on the suction pipe to the middle of the height of the pump barrel. Position of pump for a deep well: It has been customary especially in the case of railway wells to place the pump barrels in the well itself and also the A frame and working handles on a platform directly over the well. This arrangement in the case of wells the water of which is intended for human consumption is distinctly insanitary. The custom is to oil the gearing of the A frame to excess and the excess oil runs down the pump rods into the water of the well forming a scum. The presence of the working coolies on a more or less loose platform directly over the well also results in contamination of the well water and the whole arrangement is one which can only be excused for its simplicity and in cases where the water is only required for locomotive purposes and the washing of carriages. Proper position for a pump in a deep well: The correct position for a pump attached to a deep well is in a pump chamber by the side of the well as shown in the drawing. The depth of this pump chamber is determined by the rule previously given that the length between the foot valve and the centre of the pump barrel shall not exceed 22 feet. The depth of the foot valve in the well shall be determined by the available supply of water. The well itself should be deepened until it is 12 feet below the assumed lowest summer water level and the foot valve should be at a height of 2 feet above the bottom of the well. Site of a well and method of construction: For information on these points readers are referred to the specification for type designs for wells, Nos. 137, 138 and 139 issued with proceedings of the Madras Sanitary Board No. 554-S., dated 7th October, 1912. The only alteration from the type designs referred to above is the provision of a metre gauge rail at the top of the vertical suction pipe to permit of easy removal and replacement of the suction pipe after repairs to the foot valve. Access to the rail will be by means of the step irons shown in the drawing as affixed to the steining of the well. It will be observed from the drawing that the parapet of the well is shown 7 feet in height and the well is shown without a roof. Such a construction is suitable for wells which are not located near an insanitary area and close to a road from which large quantities of dust would be blown into the well. In such cases the well should be covered as shown in type designs Nos. 137, 138 and 139. In cases where the well to be provided with a pump is an old well and where for this reason local prejudice would be averse to the covering of a well as in type-designs Nos. 137, 138 and 139 it is thought that it would suffice in the meantime if the parapet was raised to a height of 7 feet as shown in the drawing and the top of this new parapet was sharply sloped to discourage birds and animals from easy access to the well and also to avoid a collection of dust which would occur on the flat top of a parapet. In future, if required and considered advisable a close top as in type-designs Nos. 137, 138 and 139 can be added. Pump chamber: By the side of the well a small well or pump chamber shall be constructed 6 feet in diameter and of depth required by the instructions already given for position of pump barrels. Near the bottom of this pump chamber there will be two beams to which the pump barrels of the pump will be bolted. The suction pipe shall pass through the steining of the well at a height of nine inches above the floor of the pump chamber. The floor of the pump chamber will be of concrete and in this concrete a small sump as shown in the plan will be made to enable the spill water of the pump barrels to be pumped out of the chamber by means of a small one inch semi-rotary pump as shown in the drawing. The pump chamber will be roofed with corrugated iron as shown in the drawing. At ground there will be two beams on which the A frame of the pump will rest. Other two shorter beams of lighter section will be provided and the pump chamber will be floored with one inch thick planks and a manhole will be provided for access to the pump barrels by means of an iron ladder. The beams on which the pump barrels rest and the beams which support the A frame will be provided with holding down bolts to prevent movement of the beams due to vibration when the pump is being worked. Kite motion railway pattern pump: The water from the well will be pumped into a reservoir provided with taps from which it will be taken by the villagers. Three coolies will be required to work the pump and three coolies will be in reserve ready to take the next shift. Each shift or period of working will be for one hour when the reserve coolies will relieve those working. The pump to be employed for deep wells will be a railway pattern kite motion double barrel pump of two inch suction and two inch discharge capable of pumping 800 gallons per hour. A specification for the pump is attached. Reservoir provided with taps: The reservoir may either be constructed of galvanised wrought iron plates as described in the attached specification and shown in drawing or of masonry as shown in the same drawing. In both cases spill water platforms and leading off drains will be provided to dispose of the spill water at a distance of at least 150 feet from the well and thus prevent the soakage of contaminated water into the well. The iron tank is shown provided with two taps while

the masonry reservoir has ten taps. If an improvement on this arrangement is desired and funds are available the reservoir may be built elevated above ground sufficiently to supply a length of cast iron distribution main in the principal street of the village and as many public fountains as are required to limit the distance the people have to carry water to a maximum of 200 yards. Cost of improvements: This report is accompanied by a schedule of quantities made out for a new well according to the dimensions and conditions shown in the drawing. At Madras rates the cost of the proposals is estimated at (1) Rs. 2,850 for an iron reservoir. (2) Rs. 3,300 for a masonry reservoir. The cost of a well fitted with a deep well pump and a reservoir with taps will increase in proportion to the depth of the well required by local circumstances. The cost of working the pumps will also increase up to 100 per cent. according to the height the water has to be forced above the barrels of the pump. Specification for a double barrelled kite motion "A" frame hand power pump. Frame : The frame shall be made of wrought-iron angles, firmly bolted together to form the usual A shape frame. Four holding down bolts each eight inches long and each provided with a washer shall be provided with each frame. Crank shaft shall be of mild steel of suitable diameter to run in gun-metal bushed plummer boxes. The wear and tear to be taken up by the usual wedge and screwed bolt adjustment. Fly wheel: A cast iron fly wheel of suitable weight and diameter to be provided. Handles : A handle to be provided on the fly wheel itself and a crank handle directly on the crank shaft. The handle to be securely fixed to the crank shaft by well-made bearing surfaces and suitable keys and key-ways, and the wooden casing of the handle to be so attached that it will not readily come off or split. Connecting rods and vertical guide rods to be of wrought iron. The guide holes in the top frame piece to be bushed with gun-metal. The connecting rod ends to be provided with gun-metal bearings and suitable for adjustment by wedge and screw bolt. Pump barrels and valve boxes and valves: The pump barrels to be of gun-metal three inches inside diameter of barrel and securely bolted to the wrought-iron frame of the pump. They must also be capable of being detached and placed if necessary in a pump pit some distance below the level of the frame head. The necessary pump rods for this contingency will be separately included in the indent. The valve boxes to be of gun-metal provided with easily accessible doors so that the valves may be examined with the least possible trouble. The pump plungers to be of gun-metal without cup leather and in lieu thereof water recesses to be provided. The pump rod to be of Muntz metal and to pass through the top of the pump barrel through a suitable stuffing box and gland. The pump rod to be secured to the cross head by a suitable nut and check nut. Suction pipe, foot valve, and strainer: A suction pipe 2 inches in internal diameter and 22 feet in vertical length in four pieces each 5 feet 6 inches long to be provided. A foot valve and strainer to be provided with each pump. Two right angle bends and a short length of straight pipe as shown in the accompanying plan should also be provided. The piping to be best galvanised wrought-iron screwed tubing. Delivery pipe: Forty feet of delivery pipe, two inches internal diameter and three-quarter bends and one U bend, all of galvanised wrought-iron tubing, to be provided with each pump. Spares: Ten per cent. spares of all working and wearing parts to accompany the supply of pumps indented for. The spares are for those parts which are likely to require repair or renewal due to fair wear and tear in, say, two years' time, after the pumps are brought into use. Guarantee: The pumps shall be of similar pattern to that represented in Merryweather & Sons No. 847 N catalogue, figure 1671, section D, page 396, and classed as Merryweather Patent India Pump for hand power or similar to the pumps supplied to the Southern Mahratta Railway by Hayward Taylor & Co. in 1889 and 1907. The pumps need not necessarily be supplied by these firms, but the pumps shall be similar, up to specification and guaranteed after trial by an inspector of the India Store Department to be pumps of first class workmanship and material and of hard wearing qualities and suitable for extended use in places where facilities for repairs are few and competent fitters for such are not easily obtainable. Each pump shall be capable of pumping 800 gallons of water per hour, when worked by three small men, each of equal power to an ordinary Indian coolie, without undue effort, at 30 revolutions per minute from a depth of 22 feet suction and the water to be delivered to a height of 17 feet above the level of the centre of the pump barrels. Galvanised wrought-iron water tanks: Each tank shall be of dimensions $8' \times 4' \times 4'$ and shall be made of galvanised wrought-iron sheets 3/16 inches thick and efficiently riveted so as to make the jointing of plates watertight. Each tank shall be provided with a closed top and a manhole opening provided with a cover capable of being locked. The manhole clear opening shall be 20 inches in diameter and the opening shall be strengthened by a wrought-iron angle ring. As shown in the plan each tank shall be provided with two galvanised iron bib cocks screwed or bolted into a flange riveted to the side of the tank. The bottom of the tank shall be dished to the extent of $\frac{1}{2}$ an inch so as to draw all water in the tank to the centre. At this place a 2 inch galvanised iron stop

cock shall be provided to be opened by a spanner to enable the tank to be scoured out periodically when cleaning is necessary. There shall be a 2 inch hole in the top of the tank at the side and four holes suitable for bolting up the flanged end of the U pipe which will be obtained with the pump as per pump specification and accompanying plan.

Abstract Of Quantities For A Deep Well With Pump And Iron Tank With Taps Or Masonry Reservoir With Taps: Plate 157.

Quantity.		Description of work.
		Design with W. I. tank.
		Deep-well, 10 feet diameter, including pump, etc., as per details attached.
		Galvanized wrought iron tank, leading off drain, taps, pipes, etc., as per details attached.
		Unforeseen works, 5 per cent.
		Contingencies, 5 per cent.
		Petty supervision, 2½ per cent.
		Total Rs...
		Alternative design with masonry reservoir.
		Deep well, 10 feet diameter, including pump, etc., as per details attached.
		Masonry reservoir including leading off drain, taps, etc., as per details attached.
		Unforeseen works, 5 per cent.
		Contingencies, 5 per cent.
		Petty supervision, 2½ per cent.
		Total Rs...
		Deep well, 10 feet diameter.
14,246 c. ft.	...	Earthwork, excavating and refilling.
94 „	...	Concrete in chunam.
596 „	...	Brickwork in chunam with weep holes every 4 feet horizontal and 2 feet vertical distances.
1,728 „	...	Brickwork in chunam.
2,153 sq. ft.	...	Plastering with cement, ½" thick.
1 No.	...	Well curb, 10' diameter, made up of 3" planks in three layers and of a form slightly larger in diameter, about 2", than the 10 feet well including angle iron cutting edge, ¾" holding down bolts, 6 feet long, etc., complete.
12 r. ft.	...	Sinking well, 10 feet diameter.
23 sq. ft.	...	Teak batten doors.
23 „	...	Do. windows.
5 „	...	Ventilators.
12 c. ft.	...	Cutstone work.
25 r. ft.	...	S.I. Railway old rails.
4 c. ft.	...	Teak timber, wrought and put up.
36 sq. ft.	...	Planking, 1" thick.
50 lb.	...	Iron-work.
72 sq. ft.	...	Corrugated iron sheets for roofing.
12 r. ft.	...	Ladder, 12" wide.
12 No.	...	Wrought-iron steps.
1 No.	...	Improved "A" frame kite motion pump, lift and force pump as per Fig. 1671, page 396 section D of Messrs. Merryweather and Sons catalogue including pump, rods, roller guides, suction, delivery pipes, etc., complete including fixing charges.
1		1" service rotary pump including suction, delivery pipes, etc., complete.
		Bailing or pumping water during sinking.
		Total Rs...
		Galvanised W. I. tank.
121 c. ft.	...	Earthwork, excavating foundations.
91 „	...	Concrete in chunam.
69 „	...	Brickwork in chunam.
279 sq. ft.	...	Plastering with cement, ½" thick, 1 : 3.
150 r. ft.	...	6" drain.
		Wrought iron tank, 8' × 4' × 4', capacity 800 gallons with manhole and cover including scour pipe, 2 cocks, etc., and fixing complete.
		Total Rs...
		Masonry reservoir with taps.
1,227 c. ft.	...	Earthwork, excavating foundations.
540 „	...	Sand filling.
696 „	...	Concrete in chunam.
27 „	..	Cement concrete.
912 „	...	Brickwork in chunam.
1,340 sq. ft.		Plastering with cement, ½" thick, (1 : 3)
3 No.	...	Wrought-iron steps.
150 r. ft.	...	6" drain, open.
5·58 c. ft.	...	Teak timber, wrought and put up.
2 No.	...	Finials.
19 sq. ft.	...	Expanded metal.
Sum		Doors with teak frames and expanded metal shutters.
159 sq. ft.	...	Roofing with 18 B.W.G. corrugated iron sheets.
4 lb.	...	Iron work.
10 No.	...	¾" galvanised W.I. tubes with stop-cocks, reducing coupling, ¾"×½", etc., including fixing complete.
		Inlet scour and overflow pipe connections.
		Total Rs...

A Deep Well (When The Maximum Water Level Is Very Low) Fitted With Pumps And Tank: Plate 158.

In the above plate is illustrated the type design No. 151 issued with proceedings of the Madras Sanitary Board, No. 162-S., dated 26—2—1914. The specification report which accompanied this design was as follows: When the depth of the lowest summer water level is more than that shown in the type design No. 145, the disposition of the pump, barrels, suction pipe, etc., should be as shown in this type design. 2. Position of pump: In the

case of deep wells the water of which is intended for human consumption the correct position for a pump is in a pump chamber built by the side of the well as shown in the drawing. 3. Depth of chamber: The depth of this chamber is determined by the rule that the length between the foot valve and the centre of the pump barrel shall not exceed 20 feet. 4. Site of well and method of construction: Specifications for type designs for wells Nos. 137 to 139 issued with the Sanitary Board's proceedings No. 554-S., dated 7th October 1912, shall be adopted with the exception that the steining of the well shall be built to a height of 8 feet from M.W.L. and the whole well shall be covered up with a reinforced concrete slab. An expanded metal door 3′ × 4′ will be provided in the steining of the well above the suction pipe for passage from the pump chamber. 5. Pump chamber: By the side of the well a small well or pump chamber, 6 feet in diameter, shall be constructed, the depth of which will be determined by the rule already given under head 3 above. 6. Roofing: The pump chamber will be roofed with corrugated iron sheets. 7. Flooring: The floor of pump chamber will have iron gratings over teak beams with an opening in the centre for access to the pump barrels by means of an iron ladder. 8. Landings: Landings in pump chamber at vertical distances of 18 feet will be provided by means of 1″ teak planks over teak joists. 9. Sump pit: A small sump as shown in the plan will be provided in the concrete bed of the pump chamber to enable the spill water of the pump barrels to be pumped out of the chamber by means of an one inch semi-rotary pump. 10. Fittings: The pump barrels of the pump will be bolted to the two beams placed across the bottom of the pump chamber. The suction pipe shall pass through the expanded metal doorway provided in the steining of the well at a height of 9 inches above the floor of the pump chamber. The A frame of the pump will rest on the 2 beams provided for the purpose over the pump chamber at ground level. Holding down bolts will be provided to prevent movement of the beams due to vibration when the pump is being worked. 11. Miscellaneous: For further information on pumps, tanks, reservoirs, etc., a reference may be made to the specifications accompanying type designs Nos. 144 and 145 issued with the Sanitary Board's proceedings No. 413-S., dated 26th June 1913, the present design being intended to complete the set of designs for protected wells.

Abstract Of Quantities For A Deep Well (When The Maximum Water Level Is Very Low) Fitted With Pumps And Tank: Plate 158.

Quantity.	Description of work.
	Deep well.
131, 617 c. ft. ...	Earthwork, excavation and refilling.
118 „ ...	Concrete, broken stone in chunam.
1, 119 „ ...	Brickwork in lime mortar with weep holes every 4 feet horizontal and 2 feet vertical distance.
2, 613 „ ...	Brickwork in lime.
4, 953 sq. ft. ...	Plastering with cement, ½″ thick.
12 c. ft. ...	Cutstone work.
..	Well curb for 10 feet diameter well with angle iron cutting edge and holding down rods, etc, complete.
17 r. ft. ...	Sinking well.
9·31 c ft. ...	Teak timber, wrought and put up.
108 sq. ft. ...	Roofing with B.W.G. corrugated sheets, including plain ridging bolts, etc., complete.
Sum ...	Reinforced cement concrete slab, complete.
Sum ...	Expanded metal door with frames, hinges, etc., complete.
28 sq. ft. ..	Door, batten with frames, hinges, etc., complete.
34 „ ...	Teak batten windows.
No. 2 ...	Expanded metal ventilator with 1½″ × 1½″ × ¼″ angle iron frames, etc., complete.
18 sq. ft. ...	Teakwood planking, 1″ thick.
16 r. ft. ...	S. I. old rails.
Sum ...	Wrought-iron grating in four pieces with ½″ rods and 1½″ × 1½″ × ⅜″ angle iron frames.
No. 12 ...	¾″ holding down bolts with plate ¼″ thick.
60 r. ft. ...	12″ wrought-iron ladder.
No. 2 ...	Wooden finials.
..	Improved "A" frame kite motion lift and force pump as per fig. 1671, page 396, section D., of Messrs. Merryweather & Sons' catalogue, including pump, rods, roller-guides, suction and delivery pipes, bends and fixing, etc., complete.
..	1″ semi-rotary pump including suction and delivery pipes, etc., complete, including fixing.
..	Bailing or pumping charges during construction.
	Total Rs.
	Design with galvanised iron tank.
..	Galvanised wrought-iron tank leading off drain, taps, pipes, etc., as per estimate for design in plate 157.
	Unforeseen charges, 5 per cent.
	Contingencies, 5 per cent.
	Petty supervision, 2½ per cent.
	Total Rs.

Quantity.	Description of work.
	Alternative design with masonry reservoir.
	Deep well including pump, etc., as per details attached.
	Masonry reservoirs including taps, leading off drain, etc., as per estimate for design in plate 157.
..	Unforeseen works, 5 per cent.
..	Contingencies, 5 per cent.
..	Petty supervision, $2\frac{1}{2}$ per cent.
	Total Rs.

Open Wells : Plate 159.

In the above plate is illustrated the type design No. 160 issued with Proceedings of the Madras Sanitary Board No. 911-S. dated 10-10-1914. The specification report which accompanied this design was as follows : Earthwork : Excavate down to the summer water level. Deepen further to the depth contemplated by bailing out water met with using chatties, picottahs or steam plant if found necessary. The cross section of the well in the type design shows a standard size of stepping. The actual form of stepping will depend greatly on the behaviour of the soil at site. A built well is generally proposed at those places where the nature of soil is hard or stiff. 2. Steining is the masonry lining of the well. Build the steining in the form of concentric and radial lines of brick or stone masonry. From the bottom of the well to summer water level construct the steining with dry stone or brick in clay or masonry in mortar providing sufficient number of weep holes. The masonry above summer water level should be built in mortar and continued to a height of 3′ 6″ above ground level as shown in the design. 3. Broken stone filling : The space left between the steining and the excavation from the bottom to summer water level should be filled in with broken stone or pebbles. The topmost layer of broken stone at least to a depth of 6 inches should be of half inch size. 4. Clay puddle : Place the puddle backing all round the steining, commencing from the top of the $\frac{1}{2}$ inch layer of broken stone filling at summer water level up to the layer underneath the platform. All layers should be properly bonded into each other as shown in the design so as to form an impervious stratum all round the steining and under the platform. 5. Filling in with earth : This work should go hand in hand with the construction of the steining and backing of the clay puddle. Each layer should be well consolidated before a second layer is introduced. 6. Platform : Lay out the platform 6 feet wide with a suitable slope towards the surrounding drain over a levelling course of concrete, broken brick or stone in chunam, as shown in the design. 7. Leading off drain : Construct the leading off drain to a length of 150 feet to carry away the spill water from the surrounding drain of the platform. 8. Finishing : Finish the interior of the steining with $\frac{1}{2}$ inch cement plaster if of brick work and point the joints with cement if of stone work, up to the lowest summer water level. The platform with the surrounding drain, parapet and the leading off drain should also be rendered with $\frac{1}{2}$ inch cement plaster. 9. Miscellaneous : The well should be completed with pulley and bucket arrangement for drawing water as shown in the design. As a sanitary improvement of first importance the ropes and buckets used in a public well should be supplied by the Local Body concerned and no private ropes or buckets or any other receptacles for drawing water should be permitted. Sunk well : 10. Earthwork : Excavate to summer water level. A sunk well is generally proposed at those places where the nature of soil is soft, sandy and is easily removed by well-sinkers. 11. Curb : Nail together three inch planks of any country wood to break joint and of different widths in three layers. Cut this curb inside and outside to shape slightly larger in diameter, say about 2 inches, than the well to be constructed. Fasten the angle iron $3'' \times 3''$ to serve as a cutting edge to the lowest plank of the curb. At about 4 feet interval in the central circumference of the curb thus formed secure $\frac{3}{4}$ inch holding down bolts, 6 feet long, the number being determined by such circumference. Place the curb, cutting edge side down, in position at summer water level. 12. Steining: Construct over the curb, brick or stone masonry to a height of say 6 feet leaving the requisite number of weep holes at 4 feet horizontal and one foot vertical intervals when lime or cement is used in the construction. Place plate washers over the holding down bolts and screw them tight in position by suitable nuts after the masonry sets. 13. Sinking: Scoop out from under the curb equally along the circumference inside the well till the loaded curb sinks to nearly 6 feet using bailing baskets or other local contrivance, for dredging. Add on a further depth of, say, 6 feet to the steining already sunk, continue the operation of sinking after the construction is well set, until the required depth is attained. The masonry above summer water level should be built in mortar and continued to a height of 3 feet 6 inches above ground level as shown in the design. 14. Clay puddle : Lay the puddle backing from the summer water level up to the layer underneath the platform, care being taken that each layer is bonded with the other so as to form an impervious stratum all round the steining and under the platform. 15. Earthfilling : This work should be carried out as specified for 'built

well, item 5. 16. Platform, leading off drain, and other miscellaneous work should be carried out as specified for built well, items 6, 7, 8 and 9.

Abstract Of Quantities For An Open Well: Plate 159.

Quantity.	Description of work.
	Built well, 10' diameter.
17,232 c. ft.	Earthwork, excavation.
6,979 „	Filling in with earth.
1,610 „	Broken stone filling.
4,148 „	Clay puddling.
699 „	Brick in clay for steining of well.
1,462 „	Brick in chunam for steining of well.
153 „	Concrete, broken brick in chunam.
2 „	Cutstone work.
20 r. ft.	Flat bottom, S.I.R. rails (old).
1,496 sq. ft.	Cement plastering, ½" thick.
150 r. ft.	6" leading off drain.
Lump sum.	Pulleys, buckets, ropes and fixing, etc., complete.
„	Bailing or pumping water during construction.
	Unforeseen works at 5 per cent.
	Contingencies at 5 per cent.
	Petty supervision at 2½ per cent.
	Total Rs.
	Sunk well, 10' diameter.
8,370 c. ft.	Earthwork, excavation.
2,899 „	Filling in with earth.
2,446 „	Clay puddling.
542 „	Brickwork in chunam with weep holes at every 4' horizontal and 1' vertical.
1,191 „	Brickwork in chunam.
153 „	Concrete, broken brick in chunam.
2 „	Cutstone work.
20 r. ft.	Flat bottom, S.I.R. rails.
1260 sq. ft.	Cement plastering, ½" thick.
150 r. ft.	6" leading off drain.
Lump sum.	Pulleys, buckets, ropes, etc.
„	Bailing or pumping water.
10 r. ft.	Sinking, 10' diameter well.
1. No.	Well curb for 10' diameter well made up of 3" plank in 3 layers and slightly (2") larger than the well including L iron cutting piece 3" × 3" with ¾" holding down bolts, etc., complete.
	Unforeseen works at 5 per cent.
	Contingencies at 5 per cent.
	Petty supervision at 2½ per cent.
	Total Rs.

A Deep Well Fitted With Semi-Rotary Hand Pump: Plate 160.

In the above plate is illustrated the type design No. 161 issued with proceedings of the Madras Sanitary Board, No. 973-S., dated 29-10-1914. The specification report which accompanied this design was as follows: Type design for fixing semi-rotary hand pumps to deep wells: The proposed type design shows only the method of fixing semi-rotary pumps to deep wells referred to in Sanitary Board type design No. 145. This is not intended to supersede type design No. 145, which should be adopted in preference to semi-rotary hand pumps for villages that can afford to pay the working cost or the wages of pumping coolies. But this new type design will be used for deep wells in villages that cannot afford to pay the wages of pumping coolies required for working a railway pattern kite motion hand pump and which have, therefore, to be provided with a pump which can be worked by each person wishing to obtain water from a well. Position of semi-rotary pump in a deep well: A semi-rotary hand pump should be fixed in a pump chamber. The rule for determining the depth of pump chamber below ground will be same as that given in Sanitary Board type design No. 145, that is, the pump must not be more than 20 to 22 feet above lowest water level in summer. Pump chamber: A small pump chamber 4'×3' (internal dimensions) is sufficient for fixing two semi-rotary pumps. A well may have one or more pump chambers according to the actual requirements. The pump chamber may be added to an existing well or to a new well after it has been constructed. The semi-rotary pumps will be fixed to the side walls of the pump chamber in the same way as they are fixed to the parapet wall of a shallow well according to the specification contained in Sanitary Board type design No. 137. But the suction pipe shall pass through the steining of the well at height of 9 inches above the floor of the pump chamber. The floor of the pump chamber shall be of concrete as shown in plan, and the floor and walls of the pump chamber shall be plastered with cement. Projecting stones shall be fixed on the walls of the pump chamber for easy access into the bottom of the pump pit when necessary. The front and side walls of the pump chamber are raised 6 inches above the platform level to prevent the entrance of spill water and the opening is covered by a Cuddapah slab as shown in plan. Two vertical Cuddapah slabs fixed on the top of side walls of the pump chamber and inserted into well steining at one end support the vertical delivery pipe and the tap. Working gear or apparatus: The apparatus used for working the pump consists of (1) one pump bar handle, (2) two connecting shackles, (3) two strainer bolts, (4) two 3/8" round iron connecting rods, (5) one iron standard, (6) one beam lever handle, (7) one wooden beam supporting the iron standard and (8) one cover for the beam lever handle. These component parts of the working gear are shown in plan. The wooden beam is fixed on the top of the pump chamber at the inner edge of the side walls flush with the top level of the Cuddapah slab covering stones. The pump bar handle is inserted into the pump spindle instead of the usual wooden handle and secured to

it by a nut and check nut similar to the usual wooden handle. The iron standard rests on the middle of the wooden beam and is firmly secured by two iron bolts and nuts with washers. The beam lever handle moves freely in a vertical plane on top of the iron standard and is connected to the iron base by an iron pin or bolt. This beam lever handle works the pump bar handle by means of two $\frac{5}{8}''$ round iron connecting rods attached to it and to the lever handle on the pump by strainer bolts. The strainer bolts are inserted at the lower end of the connecting rods for adjustments when the rods are connected or disconnected from the pump handle for repairs. The length of connecting rods will vary according to the depth of the pump chamber. An air vessel is fixed above the pump at the lower end of the vertical delivery pipe. The beam lever handle is covered by an iron plate cover and secured to the Cuddapah slab by bolts and nuts. Cost of fitting up semi-rotary pumps for deep wells: The cost of the (1) pump chamber, (2) suction and delivery pipes and (3) connecting rods and the working gear will vary according to the depth of the well. But the cost of (1) semi-rotary hand pumps and (2) component parts of the working gear excluding the connecting rods will be uniform for all deep wells. A deep well should have at least one pump chamber and two semi-rotary pumps. One pump will be in use and one pump will be locked up as a reserve for use during repairs. The cost of adding one pump chamber to a deep well and fitting it up with two semi-rotary pumps including the working gear will be Rs. 260 at Madras rates. This estimated cost is for an average deep well with the lowest summer water level 30 feet below the surface of the ground or platform and constructed according to the details of the plan accompanying this specification. The actual cost of the lever handles, connecting rods and other iron work exclusive of the semi-rotary pump is about Rs. 52 at Madras. Schedule of quantities for a well of this description is also attached herewith.

Abstract Of Quantities For A Deep Well Fitted With Semi-Rotary Hand Pump: Plate 160.

Quantity.	Description of work.
	Brick type.
2,142 c. ft. ...	Earthwork, excavation and filling in.
54 „ ...	Concrete in chunam.
164 „ ...	Brickwork in chunam.
195 sq. ft. ...	Plastering with cement, $\frac{1}{2}''$ thick, (1 : 3).
6·66 c. ft. ...	Cutstone work.
6 No. ...	Drilling holes in the vertical stone slab for fixing the cover for the beam lever handle.
4 c. ft. ...	Teakwood, wrought and put up.
2 No. ...	Working apparatus of the pump consisting of one pump-bar handle, two connecting shackles with nuts, two strainer bolts, two $\frac{5}{8}''$ round connecting rods, one air vessel, one iron standard with bolts and nuts, one beam lever handle, one cover for the beam lever handle with nuts, etc., complete, including the cost of fixing.
	Reconstructing the dismantled portion of the platform, drain, etc., and other sundries.
	Contingencies at 5 per cent.
	Petty supervision at $2\frac{1}{2}$ per cent.
	Total Rs.

Abyssinian Tube Wells.

In plates 150 and 161 are shewn sketches of Abyssinian tube wells, driving plants and brass jacketed filter points. Tubes, $1\frac{1}{4}$ inch to 4 inches diameter, driven into the ground until the sub-soil water is reached with a pump fixed at the top, are termed 'Abyssinian tube wells,' 'Norton's tube wells' or 'American tube wells.' As this class of wells was first extensively used during the Abyssinian campaign these wells are popularly known as 'Abyssinian wells.' The first tube has a hard steel nozzle with the lowest length of two feet being perforated. To this special bottom pipe successive lengths of tubes are screwed on and driven into the ground in lengths by means of a 'monkey' until suitable water bearing stratum is reached. The usual depth of these tube wells is 50 feet but there are instances in which such tube wells have been driven to depths up to 150 feet. A hand pump is attached to the top of the tube after the tubes have been driven to the required depth and water has been reached. The conditions of site, nature of the strata, depth of well and capacity of the pump are factors which affect the yield of such tube wells. Under favourable conditions the yield per minute of such wells have been as follows: $1\frac{1}{4}''$, 2 to 10 gallons; $2''$, 5 to 25 gallons; $3''$, 8 to 40 gallons. Water of such tube wells should be analysed for quality in the usual manner. For such tube wells, chalk, gravel and coarse sand are suitable strata. Soft sand and clay strata are unsuitable. These tubes cannot be driven in hard rocky soil. The advantages of tube wells are: 1. They afford a cheap, ready and safe means of securing a small supply of water. 2. They are cheap and efficient means of securing temporary supplies for fairs and festivals. 3. If results of Abyssinian tube wells for quantity and quality prove unsatisfactory, the tubes may be driven deeper, or withdrawn easily and re-driven at other likely sites. 4. The tube wells are sometimes driven

in the bottom of ordinary sunk wells for the purpose of increasing the yield of such wells. The cost of tube wells will vary depending on place and local conditions. The average usual cost per foot of depth varies from Rs. 6 for $1\frac{1}{4}''$ tube wells to Rs. 10 for 2" tube wells. The minimum average cost of a well, 25 feet in depth of $1\frac{1}{4}''$ tubes is Rs. 150, including all materials and labour and Rs. 250 for well, 25 feet in depth of 2" tubes.

Artesian Wells.

Artesian wells are borings into the earth through which water rises. Sketch fig. 23, in plate 150 shews the principle of an artesian well. A permeable layer between two impermeable layers accumulates the water which enters it at its 'outcrop' in its bottom until it becomes fully saturated. When a boring is put down at A sufficiently deep to tap the water in the permeable layer, the water rises therein under pressure according to the saturation level in the porous strata. There are a number of such wells at Pondicherry. An artesian well has been put down at Kumbakonam. The note of Mr. Hutton read at the All India Sanitary Conference, 1912, is inserted here in full. " The town of Kumbakonam is situated in the delta of the river Cauvery about 200 miles south of Madras and is 32 miles from the sea and 39 miles from the head of the delta. At the head, 10 miles above Trichinopoly, the river Cauvery divides into a number of rivers as is usual in deltaic tracts. Kumbakonam may be considered as in the centre of the fan-shaped delta. I suggested in 1904 to the Madras Government that an experimental bore-hole should be made in Kumbakonam town, as it was my opinion that from time immemorial the level of the delta had been rising by deposition of silt brought by the deltaic rivers and that as is usually the case these deposits consisted of alternate layers of sand and clay. The proposal for an experimental bore-hole having been approved, a start was made in 1905. Men accustomed to boring for artesian supplies of water were obtained from Pondicherry and a 7-inch boring was put down to a depth of 200 feet which was the depth first contemplated. At this depth the sanctioned funds became exhausted, the boring being then in hard deltaic clay of a black colour. The first 15 feet of the boring was in sand and sandy earth and below this the deltaic clay existed to the point 200 feet below ground. Further funds having been obtained, the boring work proceeded but as a 5-inch boring and at a depth of 215 feet below ground, fine sand of a blue clay colour was struck. The water level in the bore-hole remained constant. The boring was continued through different layers of sand and clay to a total of 311 feet when it was finally stopped as a tool was broken and could not be removed from this depth. It was finally decided to pull up the lining pipe to the layer of coarse sand below the thick layer of clay. It was found necessary to obtain further funds and to attempt to separate the saline sub-soil water near ground level from the water in the bore pipe and this attempt was not finally successful until this year. The yield of water from the bore-hole was increased by pumping out the fine sand at the bottom of the bore pipe. The quality of the water from the bore pipe was good, the report being as follows: " From the bacteriological results obtained with the present samples it is evident that the precautions taken in water proofing the collecting well have been entirely successful, and the water is now in very good order. There is further no sign that sub-soil pollution has penetrated to the spring feeding the bore-hole, as was feared might be the case. Chemically there is a most extraordinarily high figure for free ammonia which surely must be in association with the experiments being carried out as shown in the descriptive form. There is nothing in the other results to show that such an amount of free ammonia could be due to organic pollution. In previous analyses the free ammonia was always very high, but nothing to what it is on the present occasion. In other respects the water is much as before. It is moderately hard, but the hardness is almost entirely temporary. The figure for chlorine is also high, but this must be of mineral origin." The water level in the bore pipe remained at the level first noticed, which is the same as that in the shallow wells near the site. These wells are in sand and apparently there is no difference in level between the ordinary sub-soil water and that in the deep boring. The quantity of water that can be obtained from the boring is 140 gallons per minute. At ground level a well has been constructed and the water will be pumped out of this well by means of an oil-engine driving a three-inch centrifugal pump. A small elevated service reservoir of 7,000 gallons capacity has been built and the water is distributed from this reservoir by means of cast iron pipes and public fountains. The installation will be capable of supplying 6,000 people with 10 gallons each daily. The cost of the installation has been Rs. 14,500. The principal difficulties met with during construction were (1) ingress of contaminated surface water which was ultimately excluded by lining the well with a steel caisson, (2) damage to the lining pipe of bore-hole. This pipe was made on the spot by the Pondicherry workmen engaged in the boring from sheet iron sheets 4 feet × 2 feet and $\frac{1}{16}$ inch thick. These sheets were bent round in the form of a pipe and riveted by small rivets three inches apart and one pipe was riveted to the one below by similar rivets. The pipe was never driven. After the core in the deep clay layer was extracted by means of an auger, a special tool was inserted which cut out the hole left by the extraction of the

clay core to a greater diameter than the lining pipe so that this pipe was easily moved up or down. The sand stratum core was extracted, by a sand pump with a heavy rod and this pump was lifted and lowered by means of a rope worked from a small winch. The pipes used were easily damaged and cases occurred of the passage being blocked by part of a pipe the end of which caught on a tool and was turned inwards. In future bore-holes, more substantial pipes will be used. It is doubtful how long the thin pipe will last and it may be necessary to line it with stoneware pipes or to replace it by a more substantial pipe. A remarkable result followed vigorous pumping during execution. The fine sand in the coarse sand layer at the bottom of the lining pipe came up in quantity with the water resulting in a greatly increased supply from the bore-hole."

Boring.

The word meaning of the term 'boring' is making a hole with an auger, and technically the term means the art of piercing, or making a hole in the earth. Generally, in engineering projects, such as railway, irrigation, etc., it will be necessary to examine the nature of the sub-soil at different depths from the surface of the ground. There are two obvious ways of doing this. 1st, by examining the soils in the sides and bottom of any existing pits, wells, railway cuttings, etc., situated pretty near the proposed site or line of works; 2nd, by actually sinking pits called technically 'trial pits,' and this second method is the one usually adopted. There is still a third method of testing the underlying soil of the earth, namely, by boring, and the two methods of trial pits and borings may be briefly compared as follows: (1) The cost of trial pits will be excessive when a large number of them have to be taken. (2) Trial pits cause comparatively greater damage to existing property, etc., and are unsafe in places frequented by men and animals. (3) The depth to which trial pits could be sunk is limited practically. (4) On the other hand, the disadvantage attached to the results obtained by boring is that they are unreliable: (i) The real nature of the soil as it lies in the earth cannot be made out as certain kinds of soil have to be broken or pounded before being brought up. (ii) Information as to the hardness of the soil has to be obtained by second-hand information, *viz.*, from men who work with the boring tools. It may, however, be safely asserted that a little experience and field observations will enable one to exactly guess the nature of the sub-soil from the results of borings, and it is no exaggeration to say that a common cooly will learn the thing in a very short time. In Sanitary Engineering branch, boring operations are mainly carried on to investigate the source of underground water to supply a town, village, etc. Here in addition to testing the nature of the sub-soil at various depths, the quality of underground water at such depths could also be examined with a view to determine its potability or otherwise. Where artesian conditions are favourable, the ultimate object of a bore-hole is to tap such a supply. We now pass on to consider the boring operations in some detail. Let us restrict ourselves to the method of boring to shallow depths, say, to a maximum of 100 feet under favourable conditions. The following is a list of boring tools and plant most generally required, with the object of each. The tools are illustrated in plate 150.

Tool.	Object.
Shoe nose shell with valve, fig. 1.	For bringing up loose stuff.
Open auger, fig. 2. ...	For clay and stiff soil.
Flat chisel, fig. 3. ...	For moderately hard ground.
V nose chisel, fig. 4. ...	For hard ground.
T nose chisel, fig. 5. ...	For hard ground and rocky strata.
S nose chisel, fig. 6.	For hard rock and flint.
Worm auger, fig. 7.	For loosening stuff in bore-hole.
Spiral worm, fig. 8.	For extracting broken rods.
Bell box, fig. 9.	For bringing up broken bits.
Spring dart, fig. 10.	For drawing pipes from bore-hole.
Crow's foot, fig. 11.	For extracting broken tools.
Pair of tillers, with screws, fig. 12.	For working the rods.
Short rod, with swivel-head, fig. 13.	To fit all rods.
Pair of rod wrenches, fig. 14.	For screwing and unscrewing rods.
Swivel spring hook, fig. 15.	
Lifting dog, fig. 16.	For raising rods.
Rigger and carriage, fig. 17.	
Boring rods, in 10 feet lengths, with screw joints, fig. 18.	
Joint of rods, fig. 19.	
Joint of rods, fig. 20.	

The most usual kinds of soil to be bored through are: First, soils of various degrees of stiffness, *e.g.*, clay, loam, kunkar, etc. Second, loose soils, *e.g.*, sand, gravel, pebbles, silt, etc. Third, hard soils, *e.g.*, different kinds of rock. Wherever possible, it will be found advisable to sink a pit called 'preliminary pit' of square dimensions $7' \times 7'$ to a

depth of about 8 feet and commence boring from its bottom. This method will facilitate work, and saves a good deal of delay in the progress of boring. A pit, however, is not absolutely necessary. In boring through stiff soils, the stiff soil auger is taken to commence with, its screw threads oiled and swivel rod screwed on to it. A tiller set is then fastened on to the swivel rod to form a lever, and the auger with the attachments is held upright in a small hole made by jumping a crow bar two or three times into the ground or the bottom of preliminary pit. Steadying the whole plant, and holding it quite plumb until it sinks a few feet, a rotatory motion is given to the plant *in the direction of the hands of a clock*, applying a slight downward pressure over the tillers during rotation. The auger sinks into the ground piercing a hole and collecting the soil in the longitudinal slit provided for the purpose. When the auger has sunk to a sufficient depth, the whole thing is lifted up, the clay collected in the slit scooped out, and the whole operation repeated over and over again. When about three feet has been bored through, two men can seat themselves on the tiller rods to give downward pressure for the tool, and additional pressure can be given by attaching two hand dogs to the lengthening rod over tillers in a transverse direction to the same and two more men seating themselves on the hand dogs. In boring through the second class of soils, *viz.*, sand, gravel, pebbles, etc., a different method is followed. In this case, the bore-hole will not stand by itself as in the case of clay owing to the soil from the sides slipping. Hence the hole has to be lined which is done by sinking wrought iron tubes, called "boring tubes" as the bore-hole proceeds. A tripod is first raised over the spot of bore-hole, and a pulley suspended at its top with a manilla rope slung around the same, and the swivel rod attached to one end of the rope. The tripod should be of different height, else a lot of annoyance will be caused when working with the nose shell auger. A very convenient height will be when the poles forming the tripod are 30 feet long, and they are worse than useless when of a shorter length than 25 feet. Having erected the tripod, a lining pipe is taken, a pipe clamp attached at a convenient point of its length, and the pipe with the clamp held upright on the spot (if possible, stay it by burying a short length, say 2 feet). Then the swivel rod is screwed on to a nose shell auger and both lowered into the pipe slowly. If the length of the swivel rod be found insufficient, one of the 10 feet lengthening rods can be used. When the tool reaches the bottom of the bore-hole, it is worked up and down continuously by men who hold the other end of the rope. In this operation the sand or loose material gets into the socket of the nose shell auger and fills it as the valve at the bottom of the tool keeps the same from stripping out again. As jumping goes on, the lining pipe sinks down of itself in the first stages of boring thus clearing a hole through the loose soil. When the nose shell auger is filled with sand (indicated by the lining pipe not sinking further when the tool is worked) it is hauled up, detached from the rods, and contents emptied. The operation is repeated to continue bore-hole to further depths. The loose soil should be mixed up with water in working the nose shell auger. If subsoil water be lower than 5 feet below ground level, keep on adding a quantity of water to the bore-hole until water level is reached. The pipe should be carefully held up quite plumb until it sinks, say 5 feet: then the boring platform is fixed to the pipe and some of the men now get over the platform and work from there. The additional weight on the pipe now put on will generally be found sufficient to cause the tubes to sink of themselves till about 15 feet deep. Beyond this depth, a rotatory motion should be given to the lining pipe as the nose shell auger is worked, by means of two levers formed by letting in two crow bars at opposite ends into the open spaces between a pair of clamps fixed to the pipe. When the pipe has sunk about 35 feet, additional weight has to be put on the platform in the shape of either sand bags or some heavy iron materials lying on the works. As each pipe sinks nearly to the full depth another one is screwed on to its top. In driving pipes down, only weighing and rotating method should be used, and *on no account* should blows be given at their tops, even by placing a wooden log, etc., to act as a cushion. Hammering at top will only result in injuring the top of pipes and screw threads, with the result that succeeding pipes cannot be screwed on to them. When boring deep, say beyond 70 feet, other contrivances for pressing pipes down are used, as rotation may cause damage to the screw threads. There is one important point to be very careful about in working with the nose shell auger, that is, to avoid what is called a 'stick-fast.' The nose shell auger should never be allowed to rest even for a few seconds at the bottom of the bore-hole, else the inrushing sand and grit, along with the spring, jams the tool fast in the pipe. As soon as the tool is filled with sand, or if it be found necessary to stop jumping for a short time in the middle the tool should be hauled up, say 10 or 15 feet and then allowed to rest in the pipe of the bore-hole. If, in spite of precaution a stickfast should occur, (it invariably does until the workmen themselves experience the thing once or twice) it is useless to attempt to extract the tool by merely pulling up without the aid of jacks; no recourse whatever should be taken to such devices as twisting, etc., in the hope of loosening the tool and pulling it up

which only makes matters worse. The easiest way to tackle the thing is to raise the lining pipes bodily about 6 inches every time to about 2 feet and keep on giving an upward jerk to the tool and rods by means of the rope. The sand or grit jamming the tool sinks down and in the majority of cases the tool comes up. Where alternate strata of sand and clay have to be bored through a combination of the two methods described till now will be used. In this case, the lining pipes have to be sunk through clay also to reach the underlying sand. Lastly, in boring through hard soils such as rocks, etc., which do not yield to stiff soil auger, they are first broken and pounded by chisel (either flat or V) and the soil thus loosened is brought out by the stiff soil or nose shell auger. Such, in brief outline, are the methods followed in taking borings of a simple nature. For deep borings and in special cases, elaborate and complicated arrangements and tools are necessary.

Proposals For Tanks And Wells.

All proposals for tanks and wells should be accompanied by: "1. Site-plan showing (i) position of work; (ii) sources of supply; (iii) drainage area; (iv) villages, huts, &c., within the catchment area. 2. Enlarged plan of tank or well with sections showing details. 3. Estimate in the prescribed form. 4. Report which should contain the following particulars: (i) Description of sources of supply. (ii) Description of catchment area with statement of character of the surface; villages, huts, &c., within it and the population. (iii) Description of the feeding channels if the work is a tank. (iv) Description of the tank or well, stating whether it is a (*a*) tank fed by surface water direct; (*b*) tank fed by channels; (*c*) draw-well fed from bottom only; (*d*) step well or small tank fed by springs, or by surface drainage, or by both. (v) Description of the strata in which the work is placed, also (*a*) maximum and minimum depths of water at present; (*b*) present capacity; (*c*) dates between which it receives its supply; (*d*) date at which it is at its minimum level, or months during which it is empty. (vi) Description of improvements contemplated to its (*a*) area; (*b*) feeders; (*c*) tank itself; and if a drinking water tank the measures proposed to be taken to improve or maintain the purity of the supply. (vii) If the proposal is for deepening a tank the proposed disposal of the earth or sludge to be removed from the tank and the measures to be taken to prevent future deposit should be specified. Proposals for tank improvements should have in view (i) an increase in quantity of the water-supply, if deficient; (ii) purification of supply, if used for dietetic purposes; (iii) prevention of pollution by fencing, provision of wells, pumps, &c."

Simple Sanitary Improvements For Conserving Village Tank Water Supplies : Plate 162.

In the above plate is illustrated the type design No. 114 issued with proceedings of The Madras Sanitary Board No. 281-S, dated 4-5-1912. The specification report which accompanied this design was as follows: Nearly every village in the Presidency of Madras is in possession of one or more tanks used for drinking water-supplies and for washing purposes of men and animals. The tanks which are used for drinking water supplies are filled from irrigation channels usually once a year and the tanks are ineffectually conserved at present by means of watchmen and indifferent fencing and regulations. Water is withdrawn by the village people from these tanks in pots and in doing so the people actually enter into the water of the tank in order to fill these pots. Access to the tank is sometimes effected by steps provided for the purpose and in many cases by simple earthen ramps. By people entering the tanks, a large amount of dust and other contaminated matter is conveyed into the water from the limbs, and pots used in the operation. The Sanitary Engineer has from time to time endeavoured to improve the sanitation of these tanks by the drawing up of type designs for wells with pulley arrangements and also for platforms. These type designs, especially the latter, have not been taken up owing to the fact that, in the case of the platform, people do not use it if they can enter the tank by the ordinary means. It is therefore proposed that the conservancy of village tanks, which is being specially considered at present with the object of eliminating, if possible, epidemics of water-borne diseases, should be dealt with in the following manner. Bund: The tank bund should be sloped away from the water as shown in the type design, with the object of preventing contamination getting into the tank during rain by the washings of streets and roads and surroundings of the bund entering the tank. Fencing: Around the tank on the highest point of the bund there should be a barbed wire fence (or, preferably, any cheap form of unclimbable fencing), 6 feet high, and 6 lines of wire fastened to iron, casuarina, or stone posts, as may be locally desired. A wall is not proposed on the score of economy and also because a wall is easily scaled. Draw wells: A number of draw wells, 6 feet in diameter, should be constructed around the tank for the use of different castes. The bottoms of these wells should be connected to the tank by cast iron or stoneware pipes. Platform and leading off drains: Each well should be provided with a platform of concrete plastered with cement, and a surrounding drain which should discharge into another drain leading off into the

nearest road drain or paddy field at a distance of at least 50 yards. Pulley arrangement: For withdrawal of water there should be two sets of pulley arrangements for each well according to common use but a rope and iron bucket locally made should be provided for each pulley arrangement to prevent people using their own pots. General remarks: The proposals shown in the type design and described above are of a simple nature, and should be carried out in many hundred cases throughout the Presidency. If these arrangements are added to a village tank, an immense improvement will result in the quality of the water in the tank as there will be no chance of any contamination of the water except from the supply channel and this cannot be avoided under existing circumstances. Improvement in the water from supply channel will be effected by the powerful action of the sun during the long storage of the water in the tank. The principal object of the type design is to show a simple and inexpensive means by which the long-delayed village tank improvement may be carried out. It may be suggested that the addition of pumps and reservoirs with taps is desirable but unfortunately it is found in practice that such suggestions defeat the very object of the type design by making the improvement so expensive that it is dropped after perusal. It is therefore suggested that the addition of pumps, reservoirs, pipes, filters, etc., be omitted until the primary improvement is effected. Note: Except in stiff clay soils where there can be no percolation, the laying of the pipe should be postponed till it is seen whether there is enough percolation to keep the wells supplied.

Sacredness And Sanitation.

The most sacred of all places in South India is Rameswaram. Within the temple at Rameswaram, there are 20 wells and 3 tanks. The positions of these wells are within the temple precincts, as shewn in fig. 8, plate 222, where persons other than caste Hindus are not allowed to visit. The water of the wells and tanks is considered sacred and pilgrims resorting to Rameswaram bathe in these wells and tanks. The sub-soil of all the wells and tanks is disintegrated rock at a depth of 5 to 7 feet below ground. In all cases the steining is of masonry above the rocky stratum to ground level. It is no exaggeration to say that at the time of my inspection in 1910, most of the wells had no parapet walls, raised platforms, surrounding drain and a leading off drain, with the inevitable result that the washings of pilgrims got back into the wells. The depths of water in the wells varied from 1 foot to 3 feet. Considering the large number of pilgrims that resort to bathe in these wells and as the stratum is disintegrated rock with little in-flow, it is probably necessary to allow the sullage back into wells. There is no doubt that all wells in the temple should be provided with proper platforms, parapet walls, surrounding drain and leading off drain.

Service Reservoirs.

Service reservoirs are intended to store a reserve for supply during repairs, and to act as a regulator of pressure in the distribution pipes. Reservoirs may be entirely below ground, partly below and partly above ground, entirely above ground or elevated. A design of a small elevated reservoir is shewn in plates 175, 176 and 177; and a reservoir entirely above ground is shown in plate 166. The capacity of these reservoirs depends upon the period during which pumping is done at headworks. Usually for town water supply schemes, these reservoirs are made to hold $\frac{1}{3}$ of a day's supply. When the pumping is done continuously all the 24 hours of the day, a service reservoir with a minimum capacity of $\frac{1}{8}$ of a day's supply is considered sufficient to supply the additional requirement during hours of maximum demand.

WATER SUPPLY: DETERMINATION OF YIELD FROM SPRINGS AND DISCHARGE FROM CHANNELS AND SMALL STREAMS; SIMPLE METHODS OF CALCULATING THE DISCHARGE OF SMALL CHANNELS.

Gauging Streams.

The simplest way of ascertaining the flow of a small stream or spring is to catch the water in a kerosine oil tin of 4 gallon capacity or in a vessel of known capacity and to make a careful note of the time to fill it. This method is only applicable to very small supplies. Springs afford good sources of supply to small communities. If a stream flows from the spring, the discharge can be measured as described later on. The volume flowing from the springs varies considerably according to rainfall and to determine the quantity available for supply from a spring, it is necessary to gauge the flow over a prolonged period of drought. In the case of streams, the gauging is conducted by measuring the depth of water passing over a weir constructed by damming the stream, (see figs. 27 and 28, plate 151). As a rule, these rectangular notches or weirs have bevelled top edges of a width of not more than $\frac{2}{3}$ that of the stream with a depth suifficent to pass all the water that is to be measured. The leakage at the sides and bottom of the weir should be prevented by puddled clay. The measuring gauge should be fixed on the upstream side, away from the weir, so that the measurements are taken in the still water and not in the depression that occurs near the weir. The depth of water flowing over the weir should not be more than a quarter of the total depth of water on the upstream side and the weir should be high enough to prevent any perceptible current. The heights of water passing over the weir should be recorded at 8 A.M. and 6 P.M. daily. These observations should be carried out after a prolonged period of drought. The discharge of the stream may then be calculated with sufficient accuracy for all practical purposes by the following formula: $Q = 4{\cdot}81\ L \times \sqrt{h^3}$, where Q = discharge over notch in cubic feet per minute; L = length of notch in feet; h = height of water above top of stake in inches. A V shaped notch is sometimes cut in the weir, the notch being of sufficient size to allow the full volume of water to discharge through it. The advantage of the V notch method is that the ratio of the wetted perimeter of the notch to the area of the outflow is the same for any depth of water passing through it. If the flow is great, a number of V notches of equal size with apexes of the notches exactly in a horizontal line spaced sufficiently farther apart are sometimes constructed. When the flow is steady the discharge in cubic feet per second is $q = \frac{4}{15}\ k\ w\ h \times \sqrt{2\ g\ h}$; where q = cubic feet per second, k is a co-efficient varying from ·59 to ·62 according to the angle, being ·59 for a right angle, h = height of water in feet measured on the upstream side in still water, w = width of the triangle in feet at top of height h. When it is a right angle notch, w is 2h and the formula becomes $q = {\cdot}3\ h^2\ \sqrt{h}$ where q = discharge in cubic feet per minute, h = height of water in inches measured in still water on the upstream side. Where it is impossible to construct a weir, the best method is to ascertain the mean velocity of the stream and the cross section; then these two multiplied together give the discharge of the stream. The velocity can be estimated by timing the passage of floating bodies down the centre of the stream over a given distance, three or four times, and average struck; this should be done where the stream is as uniform in depth and width as possible. The velocity is greatest at the surface in the centre, so to obtain the mean velocity, multiply the average struck by ·83.

Weir Table For Right-angled 'V' Notch (From One Inch to Thirty Inches Deep) Gauging Formula: $q = {\cdot}3h^2\sqrt{h}$.

h Inches.	0	$\frac{1}{16}$	$\frac{1}{8}$	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$
	Discharge (q) in cubic feet per minute.							
1	·300	·339	·403	·461	·522	·591	·665	·742
2	1·70	1·83	1·97	2·12	2·28	2·42	2·61	2·78
3	4·68	4·92	5·18	5·44	5·71	5 99	6·28	6·57
4	9·60	9·98	10·4	10·8	11·2	11·6	12·0	12·4
5	16 8	17·3	17·8	18·4	18 9	19 5	20·1	20·7
6	26·5	27·2	27·9	28·6	29·3	30·0	30·8	31·5
7	38·9	39·8	40·7	41·6	42·5	43·4	44·3	45·3
8	54·3	55·4	56·5	57·5	58·7	59·8	60 9	62·0
9	72·9	74·2	75·5	76·8	78·1	79·4	80·7	82·1
10	94·9	96·4	97·9	99·4	101	102	104	106
11	120	122	124	126	127	129	131	133
12	150	152	154	156	158	160	162	164
13	183	185	187	189	192	194	196	199
14	220	222	225	227	230	233	235	238

Weir Table For Right-angled 'V' Notch (From One Inch to Thirty Inches Deep) Gauging Formula: $q = \cdot 3h^2\sqrt{h}$.

Discharge (q) in cubic feet per minute.

h Inches.	0	1/16	1/8	3/16	1/4	5/16	3/8	7/16
15	261	264	267	270	273	275	278	281
16	307	310	313	316	319	323	326	329
17	358	361	364	368	371	374	377	381
18	413	416	420	423	427	431	434	438
19	472	476	480	484	488	492	496	500
20	537	541	545	550	554	558	563	566
21	606	611	615	620	625	629	634	638
22	681	686	691	696	701	706	711	716
23	761	766	772	777	782	787	793	798
24	847	852	858	863	869	875	880	886
25	938	944	950	955	961	967	973	979
26	1,030	10,40	1,047	1,050	1,060	1,065	1,070	1,080
27	1,136	1,140	1,150	1,156	1,160	1,170	1,176	1,180
28	1,240	1,250	1,260	1,266	1,270	1,280	1,287	1,290
29	1,360	1,366	1,370	1,380	1,390	1,395	1,400	1,410
30	1,480	1,485	1,490	1,500	1,510	1,520	1,530	1,538

Discharge (q) in cubic feet per minute.

h Inches.	1/2	9/16	5/8	11/16	3/4	13/16	7/8	15/16
1	·827	·916	1·01	1·11	1·22	1·33	1·44	1·57
2	2·96	3·15	3·35	3·55	3 76	3·98	4·21	4·44
3	6·88	7·19	7·51	7·83	8·17	8·51	8·87	9·23
4	12·9	13·3	13·8	14·3	14·8	15·2	15·7	16·3
5	21·3	21·9	22·5	23·1	23·8	24·4	25·1	25·8
6	32·3	33·1	33·9	34·7	35·5	36·3	37·2	38·0
7	46·2	47·2	48·2	49·2	50·2	51·2	52·2	53·3
8	63·2	64·4	65·6	66·8	68·0	69·2	70·4	71·6
9	83·5	84·8	86·2	87·6	89 0	90·5	91·9	93·4
10	107	109	110	112	114	115	117	119
11	135	136	138	140	142	144	146	148
12	166	168	170	172	174	176	178	181
13	201	203	206	208	210	213	215	218
14	240	243	245	248	251	253	256	259
15	284	287	290	292	295	297	301	304
16	332	335	338	341	344	348	351	354
17	384	388	391	395	398	402	405	409
18	442	446	449	451	457	461	464	468
19	504	508	512	516	520	524	528	533
20	571	575	580	584	589	593	598	602
21	643	648	653	657	662	667	671	676
22	721	725	731	736	741	746	751	756
23	803	809	814	819	825	830	836	841
24	891	897	903	908	914	920	926	932
25	985	991	997	1,000	1,010	1,016	1,020	1,028
26	1,085	1,090	1,100	1,104	1,110	1,120	1,124	1,130
27	1,190	1,196	1,200	1,210	1,220	1,224	1,230	1,240
28	1,300	1,310	1,315	1,320	1,330	1,340	1,344	1,350
29	1,420	1,426	1,430	1,440	1,450	1,456	1,460	1,470
30	1,540	1,550	1,560	1,565	1,570	1,580	1,590	1,600

Weir Table From One-sixteenth Inch Depth to Twenty-five Inches Deep. L=1 inch.

Inches.	0	1/16	1/8	3/16	1/4	5/16	3/8	7/16
		·006	·01	·03	·05	·07	·09	·11
1	·40	·43	·47	·51	·55	·60	·65	·70
2	1·14	1·19	1·24	1·30	1·36	1·41	1·47	1·52
3	2·09	2·16	2·23	2·29	2·36	2·43	2·50	2·57
4	3·22	3·29	3·37	3 44	3·52	3 60	3·68	3·75
5	4·50	4·59	4·67	4·75	4·84	4 92	5·01	5·10
6	5·90	6·00	6·09	6·18	6·28	6·37	6·47	6·56
7	7 44	7·54	7·64	7·74	7·84	7·94	8·05	8·15
8	9·10	9·20	9·31	9·42	9·52	9·63	9·74	9·85
9	10·86	10·97	11 08	11·19	11·31	11·42	11·54	11·65
10	12·71	12·83	12·95	13 05	13·19	13·31	13·43	13·55
11	14·67	14·79	14·92	15·05	15·18	15·30	15·43	15·56
12	16 73	16·86	16 99	17·12	17·26	17·39	17·52	17·65
13	18·87	19·01	19 14	19·28	19·42	19·55	19·69	19·83
14	21·09	21·23	21·37	21·48	21·65	21·79	21·94	22·08
15	23·38	23·53	23 67	23·82	23 97	24·11	24·26	24·41
16	25·76	25·91	26·06	26·21	26·36	26·51	26·66	26·81
17	28·20	28·35	28·51	28 66	28·82	28·98	29·14	29·29
18	30·70	30·86	31·02	31·18	31·34	31·50	31 66	31·81
19	33·29	33·45	33·61	33·78	33·94	34·11	34·27	34·44
20	35·94	36·10	36·27	36·46	36·60	36·77	36·94	37·11
21	38·65	38·82	39·00	39·17	39·34	39·52	39·69	39·86
22	41·43	41·60	41·78	41·96	42·13	42·31	42·49	42·67
23	44·28	44·46	44·64	44·82	45·00	45·18	45·38	45·53
24	47·18	47·36	47·55	47·72	47·91	48·09	48·28	48·46

Inches.	1/2	9/16	5/8	11/16	3/4	13/16	7/8	15/16
	·14	·17	·20	·23	·26	·30	·33	·36
1	·74	·78	·83	·87	·93	·98	1·03	1·08
2	1·59	1·65	1·71	1·77	1·83	1·89	1·96	2·02
3	2·63	2·71	2·78	2·85	2·92	2·99	3·07	3·14
4	3·83	3·91	3·99	4·07	4·16	4·24	4·32	4·41
5	5·18	5·27	5·36	5·45	5·54	5·63	5·72	5·81
6	6·65	6·75	6·85	6·95	7·05	7·15	7·25	7·35
7	8·25	8·35	8·45	8·55	8·66	8·76	8·86	8·97
8	9·96	10·07	10·18	10·29	10 40	10·51	10·62	10·73
9	11·77	11·88	12·00	12·12	12·23	12·35	12·47	12·59
10	13·67	13·80	13·93	14·04	14·16	14·30	14·42	14·55
11	15·67	15·81	15·96	16·08	16 20	16·34	16·46	16·59
12	17·78	17·91	18·05	18·18	18·32	18·45	18·58	18·72
13	19·97	20·10	20·24	20·38	20·52	20·66	20·80	20·94
14	22·22	22 35	22·51	22·65	22·79	22·94	23 08	23·23
15	24·56	24·71	24·86	25·01	25·16	25·31	25·46	25·61
16	26·97	27·12	27·27	27·43	27·58	27·73	27·89	28·04
17	29·45	29·60	29·76	29·92	30·08	30·23	30·39	30·55
18	31·98	32·15	32·31	32·47	32·63	32·80	32·96	33·12
19	34·60	34·77	34·94	35·10	35·27	35·44	35 60	35·77
20	37·28	37·45	37·62	37·79	37·96	38·14	38·31	38·48
21	40·04	40·21	40·39	40·56	40·73	40·91	41·09	41·26
22	42·84	43·02	43·20	43·38	43·56	43·74	43·92	44·10
23	45·71	45·90	46·08	46·26	46·43	46·63	46 81	47·00
24	48·65	48·83	49·02	49·20	49·39	49·58	49·76	49·93

Pipe And Channel Discharges

The simplest formulæ for calculating the discharges of streams are $Q = A \times V$, and $V = 55 \times \sqrt{D \times 2F}$; where Q=discharge in cubic feet per minute

A = wetted area of cross section in square feet, V = velocity in feet per minute, D = hydraulic mean depth in feet, or area of wetted perimeter in feet divided by length of wetted perimeter in feet, and F = fall in feet per mile. In the case of pipes flowing full, D = area of circle divided by interior circumference or diameter of pipe divided by 4. In this formula, no account is taken of the nature of the interior surface of pipe or channel. The theoretical principles governing the flow of water in pipes are: 1. The frictional resistances within the pipe and the power available for overcoming them are two opposing forces. Their relation determines the velocity of flow in a pipe. 2. The frictional resistance (*a*) varies with the nature of the interior surface of the pipe, (*b*) is proportional to the area of the wetted surface, (*c*) varies proportionately up to velocities of 6 inches per second, (*d*) varies as the square of velocity above velocities of 6 inches per second, (*e*) is not affected by differences in pressure. The formula which is considered suitable and accurate for old pipes in good condition by the Sanitary Engineer of this Presidency is the Kutter's formula, *viz.*,

$$V = \left\{ \frac{41{\cdot}6 + \frac{1{\cdot}811}{{\cdot}013} + \frac{{\cdot}00281}{S}}{1 + \left(41{\cdot}6 + \frac{{\cdot}00281}{S}\right)\frac{{\cdot}013}{\sqrt{R}}} \right\} \sqrt{R\,S}$$

where V = velocity in feet per second, S = sine of slope, R = hydraulic mean depth. The process of simplification involved in the application of this formula is so tedious, that without labour saving tables, it is impossible to use this formula. To cover cases of calculation for small water supplies, the following table calculated by the above formula is appended.

Diameter of pipe in inches.	Sine of inclination 1 / over.	Velocity in feet per second.	Discharge in cubic feet per second.	Discharge in gallons per minute.
2	100	1·008	·0219	8·1994
2	65	1·251	·0273	10·2211
2	45	1·505	·0328	12·2803
2	33	1·758	·0383	14·3395
2	25	2·021	·0440	16·4736
2	20	2·260	·0493	18·4579
2	16	2·527	·0551	20·6294
2	13	2·803	·0611	22·8758
2	11	3·048	·0664	24·8602
2	9	3·370	·0735	27·5184
2	8	3·574	·0779	29·1658
2	7	3·821	·0833	31·1875
2	6	4·127	·0900	33·6960
2	5	4·522	·0986	36·9158
2½	145	1·0109	·0344	12·8794
2½	95	1·2509	·0426	15·9494
2½	66	1·5021	·0512	19·1693
2½	48	1·7624	·0600	22·4640
2½	37	2·0081	·0684	25·6090
2½	29	2·2688	·0773	28·9411
2½	23	2·5481	·0868	32·4979
2½	19	2·8038	·0956	35·7926
2½	16	3·0557	·1041	38·9750
2½	14	3·2669	·1114	41·7082
2½	12	3·5289	·1203	45·0403
2½	10	3·8659	·1318	49·3459
2½	9	4·0752	·1389	52·0042
2½	8	4·3226	·1474	55·1866
2½	7	4·6213	·1575	58·9680
2½	6	4·9916	·1702	63·7228
2½	5	5·4682	·1864	69·7881
3	200	1·004	·0493	18·4579
3	125	1·273	·0625	23·4000
3	90	1·502	·0737	27·5933
3	66	1·755	·0861	32·2358
3	50	2·017	·0990	37·0656
3	40	2·256	·1107	41·4461
3	32	2·523	·1238	46·3507
3	26	2·800	·1374	51·4426
3	22	3 044	·1494	55·9354
3	19	3·276	·1608	60·2035
3	16	3·570	·1752	65·5949
3	14	3·817	·1873	70·1251
3	12	4·123	·2024	75·7786
3	11	4·307	·2114	79·1482
3	10	4·517	·2217	83·0045
3	9	4·762	·2337	87·4973
3	8	5·051	·2479	92·8138
3	7	5·400	·2650	99·2160
3	6	5·832	·2863	107·1907
3	5	6·389	·3136	117·4118
4	320	1·006	·0878	32·8723
4	205	1·262	·1101	41·2214
4	145	1·501	·1311	49·0838
4	105	1·767	·1542	57·7325
4	82	2·001	·1746	65·3702
4	64	2·266	·1977	74·0189
4	52	2·515	·2195	82·1808
4	43	2·767	·2414	90·3802
4	36	3·024	·2639	98·8042
4	31	3·259	·2844	106·4794
4	26	3·560	·3106	116·2886
4	23	3·785	·3303	123·6643
4	20	4·059	·3542	132·6125
4	18	4·279	·3734	139·8010
4	16	4·539	·3961	148·2998
4	14	4·853	·4235	158·5584
4	13	5·036	·4395	164·5488
4	11	5·475	·4778	178·8883
4	10	5·743	·5011	187·6118
4	9	6·053	·5283	197·7955
5	455	1·010	·1377	51·5549
5	295	1·260	·1718	64·3219
5	205	1·515	·2066	77 3510
5	150	1·774	·2419	90·5674
5	115	2 032	·2764	103·4842
5	93	2·256	·3076	115·1654
5	75	2·513	·3427	128·3069
5	62	2·765	·3770	141·1488

Diameter of pipe in inches.	Sine of inclination 1/over.	Velocity in feet per second.	Discharge in cubic feet per second.	Discharge in gallons per minute.
5	52	3·020	·4118	154·1779
5	44	3·284	·4478	167·6563
5	38	3·534	·4819	180·4234
5	33	3·793	·5172	193·6397
5	29	4·047	·5518	206·5939
5	26	4·274	·5828	218·2003
5	23	4·545	·6197	232 0157
5	21	4·757	·6486	242·8358
5	19	5·001	·6819	255·3034
5	17	5·287	·7209	269·9050
5	15	5·629	·7675	287 3520
5	14	5·828	·7945	297·4608
5	13	6·047	·8245	308·6923
6	610	1·008	·1979	74·093
6	400	1·251	·2456	91·9526
6	280	1·500	·2945	110·2608
6	205	1·756	·3448	129·0931
6	155	2·021	·3969	148·5994
6	125	2·253	·4424	165·6346
6	100	2·521	·4950	185·3280
6	84	2·751	·5403	202·2883
6	70	3·015	·5920	221·6448
6	60	3·258	·6397	239·5037
6	52	3·500	·6873	257·3251
6	45	3·763	·7389	276 6442
6	39	4·043	·7938	297·1987
6	35	4·268	·8381	313 7846
6	31	4·535	·8907	333·4781
6	28	4·774	·9371	350·8502
6	25	5·052	·9919	371·3674
6	23	5 267	1 034	387·1296
6	21	5.512	1·082	405 1008
6	19	5·795	1·137	425·6928
6	17	6·127	1·203	450·4032
7	780	1 004	·2685	100 5264
7	510	1·250	·3341	125·0870
7	355	1·504	·4020	150·5088
7	260	1·762	·4708	176·2675
7	200	2·011	·5376	201·2775
7	160	2·251	·6016	225·2390
7	125	2·548	·6811	255 0038
7	105	2·782	·7435	278·3664
7	90	3 006	·8034	300 7930
7	77	3·251	·8688	325·2787
7	66	3·512	·9387	351·4493
7	57	3 780	1·010	378·1440
7	50	4·037	1·078	403·6032
7	45	4·256	1·137	425·6928
7	40	4·514	1·206	451·5264
7	36	4·759	1·272	476·2368
7	32	5·048	1·349	505 0656
7	29	5·303	1·417	530·5248
7	26	5·601	1·497	560·4768
7	24	5·830	1·558	583·3152
7	22	6·090	1·627	609·1488
8	960	1 003	·3501	131·0774
8	620	1·257	·4390	164·3616
8	435	1·507	·5262	197·0093
8	320	1·762	·6152	230·3309
8	245	2·018	·7043	263 6899
8	195	2·264	·7903	295·8883
8	160	2·502	·8732	326·9261
8	130	2·777	·9683	362·9059

Diameter of pipe in inches.	Sine of inclination 1/over.	Velocity in feet per second.	Discharge in cubic feet per second.	Discharge in gallons per minute.
8	110	3·020	1·054	394·6176
8	95	3·251	1·134	424·5696
8	82	3·500	1·221	457 1424
8	71	3·762	1·313	491·5872
8	62	4·027	1·405	526·0320
8	55	4·276	1·492	558·6048
8	49	4·531	1·581	591·9264
8	44	4·782	1 669	624·8736
8	40	5·016	1·751	655·5744
8	36	5·288	1·846	691·1424
8	33	5 524	1 928	721·8432
8	30	5·794	2·022	757·0368
8	27	6·107	2·132	798·2208
9	1150	1·002	·4427	165·7469
9	750	1 251	·5527	206·9309
9	520	1·509	·6670	249·7248
9	385	1·759	·7774	291·0586
9	295	2 014	·8899	333·1786
9	235	2·260	·9984	373·8010
9	190	2·516	1·111	415·9584
9	155	2·787	1·234	462·0096
9	130	3·045	1·345	503·5680
9	110	3·312	1·463	547·7472
9	98	3·509	1·550	580·3200
9	85	3·769	1·665	623·3760
9	75	4·014	1·773	663·8112
9	66	4·279	1·890	707·6160
9	59	4·527	2·000	748·8000
9	53	4·777	2·110	789·9840
9	48	5 020	2·218	830·4192
9	43	5·305	2·343	877·2192
9	40	5·500	2·430	909 7920
9	36	5·798	2·561	958 8354
9	33	6·057	2 675	1001·5200
9	1350	1·000	·5456	204·2726
10	880	1·250	·6821	255·3782
10	610	1·510	·8238	308·4307
10	455	1·754	·9569	358·2634
10	350	2·004	1 093	409·2192
10	275	2·265	1·235	462·3840
10	225	2 507	1·367	511·8048
10	185	2·767	1·509	564·9696
10	155	3·025	1 650	617·7600
10	130	3·305	1·802	674·6688
10	115	3·514	1·913	716·2272
10	100	3·770	2·057	770·1408
10	88	4·020	2·192	820·6848
10	78	4·270	2·329	871·9776
10	70	4·509	2·459	920 6496
10	63	4·753	2·592	970·4448
10	56	5·042	2·750	1029·6000
10	51	5·284	2·882	1079·0208
10	47	5·505	3·002	1123·9488
10	43	5·756	3·139	1175·2416
10	39	6·044	3·296	1234·0224
11	1,550	1·002	·6612	247·5533
11	1,000	1·260	·8318	311·4259
11	710	1·504	·9927	371·6669
11	520	1·764	1·164	435·8016
11	405	2 003	1·322	494·9568
11	320	2·258	1·490	557·8560
11	260	2·508	1·655	619·6320
11	215	2·761	1·822	682·1568

Diameter of pipe in inches.	Sine of inclination 1 over.	Velocity in feet per second.	Discharge in cubic feet per second.	Discharge in gallons per minute.
11	180	3·019	1·993	746·1792
11	155	3·255	2·148	804·2112
11	130	3·556	2·346	878·3424
11	115	3·782	2·496	934·5024
11	100	4·066	2·683	1004·5152
11	91	4·263	2·813	1053·1872
11	81	4·509	2·976	1114·2144
11	73	4·751	3·136	1174·1184
11	65	5·035	3·323	1244·1312
11	52	5·286	3·488	1305·9072
11	54	5·526	3·647	1365·4368
11	49	5·802	3·828	1433·2032
11	45	6 054	3·995	1425·7280
12	1750	1·005	·7894	295·5514
12	1150	1·253	·9844	368·5594
12	810	1·502	1·180	441·7920
12	600	1·753	1·376	515·1744
12	460	2·007	1·576	590·0544
12	365	2·258	1·773	663 8112
12	295	2·514	1·975	739·4400
12	245	2·762	2·169	812·0736
12	205	3·022	2·374	888·8256
12	175	3·273	2·570	962·2080
12	150	3·537	2·778	1040·0832
12	130	3·800	2·984	1117·2096
12	115	4·042	3·174	1188·3456
12	100	4·335	3·405	1274·8320
12	92	4·520	3·550	1329·1200
12	83	4·760	3·738	1399 5072
12	75	5·008	3 933	1472·5152
12	68	5·261	4·132	1547·0208
12	62	5·510	4·327	1620·0288
12	56	5·798	4·555	1705·3920
12	52	6·018	4·726	1769·4144
13	1950	1·009	·9303	348·3043
13	1300	1·250	1·152	431·3088
13	910	1·504	1·386	518·9184
13	670	1·761	1·623	607·6512
13	520	2·004	1·847	691·5168
13	410	2·262	2·085	780 6240
13	335	2·506	2·310	864·8640
13	275	2·770	2·552	955·4688
13	230	3·031	2·793	1045·6992
13	200	3 251	2·997	1122·0768
13	170	3·529	3·253	1217·9232
13	150	3·758	3·464	1296·9216
13	130	4 038	3·722	1393·5168
13	115	4·294	3·959	1482·2496
13	100	4 607	4·246	1589·7024
13	94	4·752	4·380	1639·8720
13	84	5·028	4·634	1734·9696
13	77	5·252	4·841	1812·4704
13	70	5·509	5 077	1900·8288
13	64	5·762	5·311	1988·4384
13	59	6·002	5·532	2071·1808
14	2200	1·002	1·068	399·8592
14	1450	1·250	1·333	499·0752
14	1000	1·516	1·617	605·4048
14	750	1·758	1·875	702·0000
14	580	2·005	2·139	800·8416
14	460	2·256	2·406	900·8064
14	375	2·503	2·669	999·2736
14	310	2·756	2·940	1100·7360

Diameter of pipe in inches.	Sine of inclination 1 over.	Velocity in feet per second.	Discharge in cubic feet per second.	Discharge in gallons per minute.
14	260	3·012	3 212	1202·5728
14	220	3·277	3·495	1308·5280
14	190	3·529	3·763	1408·8672
14	165	3·788	4·040	1512·5760
14	145	4·042	4·311	1614·0384
14	130	4·270	4·554	1705·0176
14	115	4·542	4·844	1813·5936
14	105	4·753	5 070	1898·2080
14	94	5·025	5·359	2006·4096
14	86	5·254	5·604	2098·1376
14	78	5 518	5·885	2203·3440
14	71	5·784	6·169	2309·6736
14	66	6·000	6·399	2395·7856
15	2400	1·008	1·237	463·1328
15	1600	1·250	1·534	574·3296
15	1100	1·520	1·865	698·2560
15	830	1·758	2·157	807·5808
15	640	2·008	2·465	922·8960
15	510	2·255	2 767	1035·9648
15	415	2·504	3·073	1150·5312
15	345	2·750	3·374	1263·2256
15	290	3·002	3·684	1379·2896
15	245	3·270	4·012	1502·0928
15	210	3·533	4·336	1623·3984
15	185	3·767	4·622	1730·4768
15	160	4·052	4·972	1861·5168
15	145	4·257	5·224	1955·8656
15	125	4·586	5·628	2107·1232
15	115	4·782	5·869	2197·3536
15	105	5·007	6·144	2300 3136
15	95	5·263	6·459	2418·2496
15	87	5·501	6 750	2527·2000
15	79	5·773	7·085	2652·6240
15	73	6 007	7·371	2759·7024
16	2650	1·004	1·402	524·9088
16	1750	1·252	1·749	654 8256
16	1200	1·526	2·130	797·4720
16	920	1·750	2·444	915 0336
16	700	2·014	2·812	1052·8128
16	560	2·257	3·151	1179·7344
16	455	2·508	3·502	1311·1488
16	375	2·776	3 862	1445·932
16	315	3·021	4·219	1579·5936
16	270	3·266	4·561	1707 6384
16	235	3·508	4·891	1831·1904
16	205	3·753	5·240	1961·8560
16	180	4·007	5·594	2094·3936
16	160	4·251	5·935	2222·0640
16	140	4·546	6·347	2376·3168
16	125	4·812	6·719	2515·5936
16	115	5 018	7·006	2623·0464
16	105	5·252	7·333	2745·4752
16	95	5·523	7·711	2886·9984
16	87	5·772	8·059	3017·2896
16	80	6·020	8·406	3147·2064
17	2900	1·003	1·581	591·9264
17	1900	1·258	1·983	742·4352
17	1350	1·505	2·372	888·0768
17	1000	1·759	2·772	1037·8370
17	770	2·011	3·170	1186·8480
17	610	2·265	3·571	1336·9824
17	500	2·507	3·951	1479·2544
17	415	2·755	4·343	1626·0192

Diameter of pipe in inches.	Sine of inclination 1 over.	Velocity in feet per second.	Discharge in cubic feet per second.	Discharge in gallons per minute.
17	350	3·003	4·734	1772·4896
17	295	3·275	5·162	1932·6528
17	255	3·525	5·556	2080·1664
17	225	3·754	5·918	2215·6992
17	195	4·035	6·360	2381·1840
17	175	4·261	6·716	2514·4704
17	155	4·528	7·138	2672·4672
17	140	4·766	7·512	2812·4928
17	125	5·045	7·952	2977·2288
17	115	5·260	8·292	3104·5248
17	105	5·506	8·679	3249·4176
17	96	5·759	9·078	3398·8030
17	88	6·016	9·483	3550·4352
18	3,100	1·008	1·782	667·1808
18	2,050	1·259	2·224	832·6656
18	1,450	1·510	2·669	999·2756
18	1,050	1·785	3·155	1181·2320
18	840	2·002	3·538	1324·6272
18	660	2·265	4·003	1498·7232
18	540	2·509	4·434	1660·0896
18	450	2·752	4·864	1821·0316
18	375	3·019	5·335	1997·4240
18	320	3·271	5·780	2164·0320
18	275	3·531	6·240	2336·2560
18	240	3·782	6·683	2502·1152
18	210	4·046	7·149	2676·5856
18	190	4·255	7·518	2814·7392
18	165	4·567	8·070	3021·4080
18	150	4·791	8·467	3170·0448
18	135	5·051	8·926	3341·6944
18	125	5·250	9·277	3473·3088
18	110	5·598	9·892	3703·5648
18	105	5·770	10·13	3792·6720
18	95	6·025	10·64	3983·6160
19	3,400	1·000	1·971	737·9424
19	2,250	1·251	2·462	921·7728
19	1,550	1·522	2·996	1121·7024
19	1,150	1·777	3·499	1310·0256
19	910	2·005	3·947	1477·7568
19	720	2·260	4·451	1666·4544
19	590	2·502	4·926	1844·294
19	485	2·764	5·442	2037·484
19	410	3·009	5·926	2218·6944
19	350	3·260	6·420	2403·6480
19	300	3·524	6·940	2598·3360
19	265	3·752	7·388	2766·0672
19	230	4·030	7·935	2970·8640
19	205	4·271	8·408	3147·9552
19	180	4·559	8·977	3360·9888
19	165	4·763	9·378	3511·1232
19	145	5·083	10·00	3744·000
19	135	5·267	10·37	3882·528
19	120	5·588	11·00	4118·400
19	110	5·838	11·49	4301·856
19	100	6·122	12·05	4511·520
20	3500	1·022	2·229	834·5376
20	2400	1·252	2·733	1023·2352
20	1700	1·503	3·279	1227·6576
20	1250	1·764	3·848	1440·6912
20	980	2·000	4·363	1633·5072
20	770	2·263	4·937	1848·4128
20	630	2·507	5·469	2047·593
20	520	2·764	6·030	2257·632
20	440	3·008	6·563	2457·1872
20	375	3·262	7·116	2664·2304
20	325	3·506	7·650	2864·1600
20	280	3·780	8·248	3088·0512
20	250	4·003	8·733	3269·6352
20	220	4·269	9·314	3487·1616
20	195	4·536	9·896	3705·0624
20	175	4·790	10·45	3912·480
20	160	5·010	10·93	4092·192
20	145	5·264	11·48	4298·112
20	130	5·562	12·12	4537·728
20	120	5·788	12·62	4724·928
20	110	6·047	13·20	4942·080

Hydraulic Gradient.

The hydraulic gradient (see fig. 26, plate 151) is the slope from the water level at the source to that at the point of discharge as shewn on line B C or as shewn along B A C when water is delivered under pressure, indicating the levels to which water would rise in vertical pipes if erected along the pipe line. No part of the pipe should rise above the gradient line. At all high points below the line of hydraulic gradient, air valves should be provided to release the accumulated air at the upward bends.

WATER SUPPLY: VARIOUS METHODS OF LIFTING WATER WITH DETAILS OF APPLIANCES USED AND THE CONSTRUCTION OF THE ORDINARY LIFT AND FORCE PUMPS.

Pumping Plant.

Judged from the character of fuel for the plant, pumping plants used in water works are classed as steam plant in which coal or wood is fuel; oil engines in which kerosine oil or liquid fuel is fuel, and gas producing plant in which anthracite or charcoal is fuel. In cases where the supply of water to be raised is small, hand pumps for manual labour are employed. The relative merits and demerits of the different classes of the pumping plant are beyond the scope of the present lectures. For small water supply schemes, Hornsby's Oil Engines and Centrifugal Pumps may be adopted.

Lift And Force Pumps.

The principle of the action of the pumps is similar to that of the syphon and other hydraulic applications and depends upon the balance of weight between a column of water of a certain height and the atmosphere. In figs. 29 and 30, plate 151, are shewn the common suction pump and the lifting pump. In the case of pumps, the best results are obtained when the suction side does not exceed 15 feet. It should, under no circumstances, exceed 20 feet. In the case of the common suction pump, fig. 29, the water is raised through a suction pipe and delivered by a discharge end which is attached to the barrel or cylinder. In the case of the lifting pump, fig. 30, a rising pipe in the place of the ordinary spout is attached with a valve at the lower end of this pipe to prevent the return of the water. In the case of the lifting pumps, the piston rod works through a stuffing-box the upper end of the barrel being securely covered down owing to considerable pressure within the pump barrel. The power required to work a lifting pump must be sufficient not only to fill the barrel from below but also to lift the column of water in the rising pipe. In the market, there are a number of hand pumps. For small supplies, one inch to one and a half inch semi-rotary pumps, as shewn in plate 156, may be adopted. Where the supply is rather large, Indian kite motion double barrel pump should be adopted. This pump is so constructed that the complete cylinders or barrels with the suction and delivery boxes attached can be taken out and erected below the frame for deep well purposes. These pumps are made in four sizes, viz., $1\frac{1}{2}$ inch capable of delivering 500 gallons per hour; 2 inch capable of raising 725 gallons per hour; $2\frac{1}{4}$ inch capable of raising 1,000 gallons per hour and $2\frac{1}{2}$ inch capable of raising 1,300 gallons per hour. The prices vary from Rs. 330 to Rs. 390.

Hydraulic Memoranda.

1. One Imperial gallon = 277·463 cubic inches. 2. One Imperial gallon = ·16 cubic foot. 3. One Imperial gallon = 10 lb. avoirdupois at 62 degrees Fahrenheit. 4. One Imperial gallon = 4·546 litres. 5. One United States gallon = 231 cubic inches. 6. One United States gallon = 8·33111 lb. 7. One cubic foot of water = 6·23 Imperial gallons (usually taken as 6·25 gallons). 8. One cubic foot of water = 7·480519 United States gallons. 9 One cubic foot of water = 62·28 lb. 10. One cubic foot of water = ·55606 cwt. 11. One cubic foot of water = ·0278 ton. 12. One cubic foot of water = 28·3116 litres. 13. One cubic foot of water = ·0283 cubic metre. 14. One cubic inch of water = 252·286 grains. 15. One cubic inch of water = ·03604 lbs. 16. One pound of water = ·10 Imperial gallon. 17 One pound of water = 27·74 cubic inches. 18. One ton of water = 224 Imperial gallons. 19. One litre of water = ·22 Imperial gallon. 20. One cubic metre of water = 220 Imperial gallons. 21. One cubic metre of water = 1 ton (approximately). 22. One Kilo. of water = 2·2046 lbs. 23. Head in feet × ·4335 = pressure in lbs. per square inch. 24. Head in feet × ·341 = pressure in lbs. per circular inch. 25 Head in feet × 62·425 = pressure in lbs. per square foot. 26. Pressure in lbs. per square inch × 2·306 = head in feet. 27. Pressure in lbs. per square foot × ·016 = head in feet. 28. A pressure of 1 lb. per square inch = column of water 2·31219 feet high. 29. A column of water 1 foot high = a pressure of ·4325 pounds per square inch. 30. Gallons contained per foot run of pipe = (diameter in inches)^2 × ·034. 31. Pounds per foot run of pipe = (dia. in inches)^2 × ·34. 32. Doubling the diameter of a pipe increases its capacity four times. 33. Discharge varies as the square root of the 'head.' 34. The friction of liquids in pipes increases as the square of the velocity. 35. The horse-power required to raise a given quantity of water in gallons to a given height is found as follows: Multiply the water to be raised in gallons per minute by 10 and by the height the water has to be raised in feet, and divide the product by 33,000. 36. The manual power (working 8 hours) required is found thus: Multiply the water to be raised in gallons per minute by 10 and by the height the water has to be raised in feet, and divide the product by 2750. Add 50 per cent. for friction.

WATER SUPPLY: PIPES AND FITTINGS.

Classification And Uses.

In water supply works, cast iron pipes are used as mains in streets, as they are considered the best class of pipes for conveying water in distribution arrangements. Cast iron pipes should, in all cases, be of standard sizes and street mains should never be less than 3 inches in diameter. The house service pipes should be galvanised wrought iron tubes. Generally speaking, pipes with flanged joints, and pipes with spigot and socket joints are the two forms of cast iron pipes. The flanged joint is used in vertical pipes and in connections with meters, valves, etc.; but the leaded joint pipes called plain pipes (see fig. 2, plate 188 are generally employed for all street mains. The spigot and socket pipes are of two classes, pipes with turned and bored joints (see fig. 1, plate 188) and pipes with lead joints (see fig. 2, plate 188). At the present day, pipes with turned and bored joints are not used as the joints are not so satisfactory as lead joints in plain pipes In turned and bored pipes, one disadvantage is that there is no allowance for expansion. Plain pipes are suitable in all situations. Turned and bored pipes are jointed in the following manner. The joints to be connected are thoroughly cleaned, then smeared with thin red lead or liquid English Portland cement. The spigot is then inserted in the socket and the pipe driven home by placing a block of wood at the other end and tapping it with a mallet. When the spigot end of the pipe has been inserted into the socket so as to be truly concentric and in a straight line with the pipes already laid, and after a reasonable length of pipes has been rammed home, the space left remaining between the inside of the socket of one pipe and the spigot of another should be filled in with nearly dry Portland cement mortar of composition 1 to 1 which shall be thoroughly well caulked into the space and the space should be neatly finished flush with the face of the socket. The object of cement jointing is to prevent the sucking into the pipe of subsoil water in the event of the turned and bored joints being slightly drawn apart owing to subsidence or contraction of the pipes themselves. $\frac{1}{4}$, $\frac{1}{8}$, $\frac{1}{16}$, $\frac{1}{32}$, bends shown in fig. 3, branch pipes shown in fig. 4, taper pipes shown in fig. 5, and collars shown in fig. 6, are jointed similar to plain pipes, fig. 2, plate 188, with lead according to the following specification of the Sanitary Engineer to Government. "After the pipes or specials are placed in correct positions for jointing, the joints shall be formed as follows. At least one complete lap of clean white hempen spun yarn shall be forced into the bottom of the socket. Several laps of tarred yarn shall then be forced into the joint and caulked tight so as to leave at least the depths of joint for the lead as noted below:

Diameter of pipe.			Depth of lead joint.
2″ to 5″	...	...	$1\frac{1}{2}$″
6″ to 12″	...	...	2″
14″ to 18″	...	...	$2\frac{1}{4}$″
20″ to 24″	...	...	$2\frac{1}{2}$″

The pipes shall rest on the bottom of the trenches throughout their entire length of each pipe except at the sockets where hollows are made to enable the jointing to be done. The pipes shall then be examined for line and level and the space left in the socket shall be filled by pouring in melted lead. This may be best done by using rubber jointing rings. When these are not available, a ring of hemp rope covered with clay shall be wrapped around the pipe at the end of the socket, leaving an opening at the top of the socket into which the lead can be poured. The hemp rope shall be supported by clay packing so as to stand the operation of lead pouring. The lead used shall be the best English silver lead free from impurities and shall be carefully skimmed of all scale when melted in a cast iron pot or patent melting machine. Sufficient lead shall then be taken from the pot by a ladle and run hot into the joint, and the joint filled at one running with lead flush with the outside of the joint which shall then be "set up" by a suitable caulking tool and a 4-lb. hammer when cool, until the lead is at least $\frac{1}{8}$ inch within the edge of socket. Lead wool joints: When the pipes are to be jointed with "lead wool" joints the following instructions shall be observed: After the pipes or specials are laid in the exact position they are to occupy, the space for jointing shall be filled with yarn and lead in the following manner. A skein of untarred yarn shall be taken and wound round the pipe and then forced into the interior of the joints by a suitable caulking tool. More skeins of untarred yarn shall be added similarly and caulked tight so as to leave at least the depths of joints for lead wool as noted below;

Diameter of pipe in inches.	Depth of lead wool in inches.	Diameter of pipe in inches.	Depth of lead wool in inches.
$2\frac{1}{2}$	$1\frac{1}{8}$	12	$1\frac{3}{8}$
3	$1\frac{1}{8}$	14	$1\frac{1}{2}$
4	$1\frac{1}{4}$	15	$1\frac{1}{2}$
5	$1\frac{1}{4}$	16	$1\frac{1}{2}$
6	$1\frac{3}{8}$	18	$1\frac{5}{8}$
7	$1\frac{3}{8}$	20	$1\frac{5}{8}$
8	$1\frac{3}{8}$	21	$1\frac{5}{8}$
9	$1\frac{3}{8}$	22	$1\frac{5}{8}$
10	$1\frac{3}{8}$	24	$1\frac{5}{8}$

A skein of lead wool shall then be taken and inserted in the joints and well caulked home with a caulking tool and a 4 lb. hammer. Further skeins shall be added and caulked until the socket is filled with well-caulked lead wool to within $1\frac{1}{8}$ inch of the outside edge of socket. The caulking tools shall be shaped to suit the circumference of the pipe being jointed and shall be somewhat less in thickness than the width of space of joint. The handles of tools shall be suitably shaped so that they may be easily driven by a caulking hammer, the weight of which shall not be less than 4 lb. Special care shall be taken with the caulking of the first two or three turns of lead wool, and also the remainder, otherwise the joint may leak. No ordinary cold chisel shall be used in jointing but only suitable caulking tools." Certain means of regulation are required in all pipe lines and service connections. Those which govern the flow of water through main pipes for turning on or off water in pipes are called sluice valves, see figs. A_2, A_3, A_4, and A_5, in plate 189. Similar valves used in service connections are called cocks. Valves used for preventing water flowing in the wrong direction are called retaining or reflux valves, see figs. 43 and 44 in plate 190. Valves used for permitting automatically the escape of air from street mains are called air valves, see figs. H_7 H_4 H_{4a} H_5, H_{21}, H_{22}, H_{23} H_{30} and H_{31} in plates 189 and 190. The valves used in outlet chambers to regulate the flow from filter beds are called filter outlet regulators, see fig. A_{118} of plate 190. Water passing through pipes are measured by meters. Meters are either direct action or inferential. As a rule, to avoid wastage and prevent the use of water to any unreasonable extent, meters are introduced at service connections. A specimen of a household meter is shown in plate 191. The taps used at service connections are of many patterns. The street fountains at municipal water works are provided generally with Tylor's Patent 'Waste-Not Self-Closing Galvanised Iron Valves.' This valve is shown in plate 191. The different parts of this valve *viz.*, 1. spindle socket and plunger, 2. spring, 3. cam spindle, 4. bush for cam spindle, 5. cam, 6. seating and guide cage, 7. bush and stuffing-box for cam spindle, 8. lever handle and 9. screw for cover, are shown in plate 191. The connection of a service pipe from a main is made by means of a stop ferrule as shown in plate 191. I am indebted to Messrs. Glenfield and Kennedy, Ltd., and Messrs. J. Tylor and Sons, Ltd., for the figures illustrated in plates 189 to 191. The details of the standard cast iron pipes and specials shown in plate 188 are given below:

Details For Cast Iron Plain Pipes.

Bore.	Length.	A	B	Thickness of pipe, C	D	E	F	G	H	I	J	K	L	M	Radius, N	Weight per length, plain spigots and sockets.				Bore.
																cwts.	qr.	lbs.	cwts.	
Inches.	Ft.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.					Inches.
2																0	2	7	0·563	2
$2\frac{1}{2}$	6	$2\frac{1}{2}$	3	$\frac{3}{8}$	$\frac{1}{4}$	$\frac{7}{8}$	$\frac{3}{4}$	1	$\frac{11}{16}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{1}{8}$	$\frac{1}{2}$	$\frac{1}{8}$	$1\frac{1}{16}$	0	2	21	0·688	$2\frac{1}{2}$
3																1	0	16	1·143	3
4																1	1	24	1·464	4
5																2	0	18	2·160	5
6		3	$3\frac{1}{2}$	$\frac{7}{16}$	$\frac{3}{8}$	1	$\frac{7}{8}$	$1\frac{1}{8}$	$\frac{13}{16}$	$\frac{11}{16}$	$\frac{7}{8}$	$\frac{1}{8}$	$\frac{1}{2}$	$\frac{1}{8}$	$1\frac{1}{16}$	2	2	6	2·554	6
7	9			$\frac{1}{2}$												3	1	11	3·348	7
8																3	3	8	3·821	8
9		3	4	$\frac{9}{16}$	$\frac{3}{8}$	$1\frac{1}{8}$	1	$1\frac{3}{8}$	$\frac{7}{8}$	$\frac{3}{4}$	1	$\frac{1}{8}$	$\frac{1}{2}$	$\frac{1}{8}$	$1\frac{1}{16}$	4	3	3	4·777	9
10				$\frac{5}{8}$												5	3	10	5·839	10
12		3	4		$\frac{3}{8}$	$1\frac{1}{4}$	1	$1\frac{3}{8}$	$\frac{15}{16}$	$\frac{13}{16}$	$1\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{2}$	$\frac{1}{8}$	$1\frac{1}{16}$	6	3	26	6·982	12
14				$\frac{11}{16}$												11	3	25	11·973	14
15		$3\frac{1}{2}$	$4\frac{1}{2}$		$\frac{3}{8}$	$1\frac{3}{8}$	$1\frac{1}{8}$	$1\frac{1}{2}$	$1\frac{1}{16}$	$\frac{15}{16}$	$1\frac{1}{4}$	$\frac{1}{8}$	$\frac{3}{4}$	$\frac{3}{16}$	$1\frac{19}{32}$	12	3	3	12·777	15
16	12			$\frac{3}{4}$												14	3	0	14·750	16
18		$3\frac{1}{2}$	$4\frac{1}{2}$		$\frac{3}{8}$	$1\frac{1}{2}$	$1\frac{1}{4}$	$1\frac{3}{4}$	$1\frac{1}{8}$	1	$1\frac{1}{4}$	$\frac{1}{8}$	$\frac{3}{4}$	$\frac{3}{16}$	$1\frac{19}{32}$	16	2	12	16·607	18
20		$3\frac{1}{2}$	$4\frac{1}{2}$	$\frac{7}{8}$	$\frac{3}{8}$	$1\frac{3}{8}$	$1\frac{3}{8}$	2	$1\frac{1}{4}$	$1\frac{1}{8}$	$1\frac{1}{4}$	$\frac{1}{8}$	$\frac{3}{4}$	$\frac{3}{16}$	$1\frac{19}{32}$	21	1	14	21·375	20

Details For Cast Iron Turned And Bored Pipes.

Bore.	Length.	A	B	Thickness of pipe, C	D	E	F	G	H	I	J	K	L	M	Radius, N	P	Weight per length, turned and bored spigots and sockets.				Bore.
																	cwts.	qr.	lbs.	cwts.	
Inches.	Ft.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.					Inches.
2	6																0	2	8	0·571	2
$2\frac{1}{2}$		$2\frac{1}{2}$	3	$\frac{3}{8}$	$\frac{1}{4}$		$\frac{3}{4}$	1	$\frac{11}{16}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{1}{8}$	$\frac{1}{2}$	$\frac{1}{8}$	$1\frac{1}{16}$	$1\frac{1}{4}$	0	2	22	0·696	$2\frac{1}{2}$
3																	1	0	17	1·152	3
4																	1	1	26	1·482	4
5				$\frac{7}{16}$													2	0	20	2·178	5
6		3	$3\frac{1}{2}$		$\frac{3}{8}$	1	$\frac{7}{8}$	$1\frac{1}{8}$	$\frac{13}{16}$	$\frac{11}{16}$	$\frac{7}{8}$	$\frac{1}{8}$	$\frac{1}{2}$	$\frac{1}{8}$	$1\frac{1}{16}$	$1\frac{3}{8}$	2	2	8	2·571	6
7	9			$\frac{1}{2}$													3	1	14	3·375	7
8																	3	3	12	3·857	8
9		3	4	$\frac{9}{16}$	$\frac{3}{8}$	$1\frac{1}{8}$	1	$1\frac{3}{8}$	$\frac{7}{8}$	$\frac{3}{4}$	1	$\frac{1}{8}$	$\frac{1}{2}$	$\frac{1}{8}$	$1\frac{1}{16}$	$1\frac{5}{8}$	4	3	8	4·821	9
10				$\frac{5}{8}$													5	3	15	5·884	10
12		3	4		$\frac{3}{8}$	$1\frac{1}{4}$	1	$1\frac{3}{8}$	$\frac{15}{16}$	$\frac{13}{16}$	$1\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{2}$	$\frac{1}{8}$	$1\frac{1}{16}$	$1\frac{5}{8}$	7	0	3	7·027	12
14				$\frac{11}{16}$													12	0	6	12·053	14
15		$3\frac{1}{2}$	$4\frac{1}{2}$		$\frac{3}{8}$	$1\frac{3}{8}$	$1\frac{1}{8}$	$1\frac{1}{2}$	$1\frac{1}{16}$	$\frac{15}{16}$	$1\frac{1}{4}$	$\frac{1}{8}$	$\frac{3}{4}$	$\frac{3}{16}$	$1\frac{19}{32}$	$1\frac{7}{8}$	12	3	14	12·875	15
16	12			$\frac{3}{4}$													14	3	13	14·86	16
18		$3\frac{1}{4}$	$4\frac{1}{2}$		$\frac{3}{8}$	$1\frac{1}{2}$	$1\frac{1}{4}$	$1\frac{3}{4}$	$1\frac{1}{8}$	1	$1\frac{1}{4}$	$\frac{1}{8}$	$\frac{3}{4}$	$\frac{3}{16}$	$1\frac{19}{32}$	$1\frac{7}{8}$	16	2	26	16·732	18
20		$3\frac{1}{2}$	$4\frac{1}{2}$	$\frac{7}{8}$	$\frac{3}{8}$	$1\frac{5}{8}$	$1\frac{3}{8}$	2	$1\frac{1}{4}$	$1\frac{1}{8}$	$1\frac{1}{4}$	$\frac{1}{8}$	$\frac{3}{4}$	$\frac{3}{16}$	$1\frac{19}{32}$	$1\frac{7}{8}$	21	2	0	21·500	20

Details For Cast Iron Bends.

Bore of pipe.	Length of chord A.B' for bends of all angles.	Radius O.A. or O.B. of bends. $\frac{1}{4}$	$\frac{1}{8}$	$\frac{1}{16}$	$\frac{1}{32}$	Length of arc. A.B. of bends. $\frac{1}{4}$	$\frac{1}{8}$	$\frac{1}{16}$	$\frac{1}{32}$	Bore of pipe.
Inches.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Inches.
2	1·50	1·06	1·96	3·84	7·65	1·67	1·54	1·51	1·50	2
$2\frac{1}{2}$	1·50	1·06	1·96	3·84	7·65	1·67	1·54	1·51	1·50	$2\frac{1}{2}$
3	1·50	1·06	1·96	3·84	7·65	1·67	1·54	1·51	1·50	3
4	1·50	1·06	1·96	3·84	7·65	1·67	1·54	1·51	1·50	4
5	1·50	1·06	1·96	3·84	7·65	1·67	1·54	1·51	1·50	5
6	2·00	1·41	2·61	5·13	10·20	2·22	2·05	2·02	2·00	6
7	2·00	1·41	2·61	5·13	10·20	2·22	2·05	2·02	2·00	7
8	2·00	1·41	2·61	5·13	10·20	2·22	2·05	2·02	2·00	8
9	2·50	1·77	3·27	6·41	12·75	2·78	2·56	2·52	2·50	9
10	2·50	1·77	3·27	6·41	12·75	2·78	2·56	2·52	2·50	10
12	3·00	2·12	3·92	7·69	15·30	3·33	3·08	3·02	3·00	12
14	3·00	2·12	3·92	7·69	15·30	3·33	3·08	3·02	3·00	14
15	3·00	2·12	3·92	7·69	15·30	3·33	3·08	3·02	3·00	15
16	3·00	2·12	3·92	7·69	15·30	3·33	3·08	3·02	3·00	16
18	3·00	2·12	3·92	7·69	15·30	3·33	3·08	3·02	3·00	18
20	4·00	2·83	5·23	10·25	20·41	4·44	4·10	4·03	4·01	20

NOTE :—Dimensions of spigot and socket will be same as for ordinary pipes.

Details For Cast Iron Branch Pipes.

Diameter.	Length.	Length.
A	B	C
Inches.	Inches.	Inches.
2	5	12
$2\frac{1}{2}$	$5\frac{3}{8}$	$12\frac{3}{4}$
3	$5\frac{3}{4}$	$13\frac{1}{2}$
4	$6\frac{1}{2}$	15
5	$7\frac{1}{4}$	$16\frac{1}{2}$
6	8	18
7	$8\frac{3}{4}$	$19\frac{1}{2}$
8	$9\frac{1}{2}$	21
9	$10\frac{1}{4}$	$22\frac{1}{2}$
10	11	24
12	$12\frac{1}{2}$	27
14	14	30
15	$14\frac{3}{4}$	$31\frac{1}{2}$
16	$15\frac{1}{2}$	33
18	17	36
20	$18\frac{1}{2}$	39
21	$19\frac{1}{4}$	$40\frac{1}{2}$
22	20	42
24	$21\frac{1}{2}$	45

NOTE :—Dimensions of spigot and socket will be same as for ordinary pipes.

Details For Cast Iron Taper Pipes.

Size.	Length. A
Inches.	Feet.
$2\frac{1}{2} \times 2$	2
$3 \times 2\frac{1}{2}$	2
4×3	2
5×4	2
6×5	2
7×6	2
8×7	2
9×8	2
10×9	2
12×10	4
14×12	4
15×14	2
16×15	2
18×16	4
20×18	4
21×20	2
22×21	2
24×22	4

NOTE :—Dimensions of spigot and socket will be same as for ordinary pipes.

Details For Cast Iron Collars.

Bore of pipe.	Length.	Length.	Length.
P	D	C	L
Inches.	Inches.	Inches.	Inches.
2	3	$\frac{3}{8}$	9
$2\frac{1}{2}$	$3\frac{1}{2}$	$\frac{3}{8}$	9
3	4	$\frac{3}{8}$	9
4	5	$\frac{3}{8}$	9
5	6	$\frac{3}{8}$	10
6	7	$\frac{3}{8}$	10
7	$8\frac{1}{8}$	$\frac{7}{16}$	10
8	$9\frac{1}{8}$	$\frac{7}{16}$	11
9	$10\frac{1}{4}$	$\frac{1}{2}$	11
10	$11\frac{1}{4}$	$\frac{1}{2}$	12
12	$13\frac{3}{8}$	$\frac{9}{16}$	$12\frac{1}{2}$
14	$15\frac{1}{2}$	$\frac{5}{8}$	$12\frac{1}{2}$
15	$16\frac{1}{2}$	$\frac{5}{8}$	13
16	$17\frac{1}{2}$	$\frac{5}{8}$	13
18	$19\frac{5}{8}$	$\frac{11}{16}$	13
20	$21\frac{3}{4}$	$\frac{3}{4}$	15

NOTE :—The sockets of collars will be same as for plain ordinary pipes.

Municipal Workshop: Plate 178.

In the above plate is illustrated the type design No. 111 issued with proceedings of the Madras Sanitary Board, No. 112-S., dated 24-3-1911. The specification report which accompanied this design was as follows: General: The workshop generally consists of: (1) Pumping station workshop measuring 30′ 0″ × 15′ 0″, with a room, for the installation of $3\frac{1}{2}$ B. H. P. Hornsby Oil Engine, on the left measuring 8′ 0″ × 8′ 0″. (2) Pumping station store measuring 12′ 0″ × 15′ 0″. There will be a covered verandah in front for a blacksmith, measuring 17′ 3″ × 10′ 0″. 2. Foundations will be 3 feet deep in the case of main and cross walls of the building. These will be built of brick in surkhi mortar. The depth of the foundations should be increased in loose soil. In a place where concrete is cheaper than brickwork, the whole of the foundations to ground level may be built of broken vitrified bricks or stones in surkhi mortar. If random rubble in surkhi mortar is also found cheaper than brickwork, the foundation masonry may be built of the former. The pressure on the soil in foundations as shown on the drawing amounts to ·69 ton per square foot. 3. Basement will be 1 foot high of brickwork in surkhi mortar. In places where stone work is cheaper than brickwork, the basement may be built of coursed rubble, first sort, in surkhi mortar. 4. Filling in of the basement should be with clean sand only. 5. Superstructure will be of brickwork in mortar. If coursed rubble, first sort, in mortar is cheaper than brickwork, the walls may be built of the former. 6. Flooring will be of Cuddapah slabs, 2 inches thick, laid on 4 inches of surkhi concrete and all joints shall be pointed to the full depth of the slab with English Portland cement. 7. Inside and outside of walls will usually be plastered with chunam, two coats. But if the walls are of coursed rubble, they should not be plastered on the outside but the joints should be neatly pointed with surkhi mortar. 8. Roofing will consist of Mangalore tile roofing over rafters placed 2 feet apart from centre to centre. 9. Doors and windows: The doors will be full panelled and windows full battened with iron bars and they will open inside. No projecting door sill pieces should be put in. 10. Woodwork: Provision in the estimate has been made for teakwood doors, windows, and roof timbers. 11. Painting: The exposed woodwork, doors and windows will be painted with at least two coats of best oil paint. 12. Shelves: There should be an ample supply of shelves in the store room as shown. 13. The cost of design will vary from Rs. 1,880 to Rs. 2,820 according to locality and that of tools and plant required for the above will be about Rs. 2,909. Note: In places where the nature of the local lime is such as to render the use of surkhi unnecessary, surkhi may be omitted.

Abstract Of Quantities For A Workshop: Plate 178.

Quantity.	Description of work.
1,339 c. ft. ...	Earthwork in excavating foundations.
332 „ ...	Filling in basement with clean sand.
1,124 „ ...	Brickwork in surkhi mortar in foundations and basement.
1,944 „ ...	Brickwork in chunam in superstructure.
82 „ ...	Archwork, brick in mortar.
664 sq. ft. ...	Flooring with 2″ Cuddapah slabs laid on 4″ surkhi concrete and neatly pointed with cement to the full depth of the slab.
3,683 „ ...	Plastering with chunam, smooth, two coats, inside and outside.
1,598 „ ...	Roofing with Mangalore tiles including teak reepers.
84 „ ...	Teakwood doors, 4′ × 7′, full panelled, including bottom cutstones, etc., complete.
141 „ ...	Teakwood windows, full battened with iron bars including frames, fittings, etc., complete.
116·8 c. ft. ...	Teakwood, wrought and put up complete.
1,994 sq. ft. ...	Painting, two coats, with silicate imperial paints.
18 r. ft. ...	Barge board, teak, 9″ depth and ½″ thick.
15 „ ...	Shelves, 1′ 1½″ width with brackets, etc., complete.
129 c. ft. ...	Gravelling including spreading, watering tamping, etc., complete.
60 l. ft. ...	Old iron rails.
53 r. ft. ...	Dental cornice.
No. 1. ...	Water tank.
	Petty charges at 2½ per cent.
	Total Rs.
	Tools and plant.
No. 1. ...	Drilling machine, No. 200 with table, base plate, vice and drills, capacity ¾″ complete with cast iron stand No. 209 as per George Hatch and Company's catalogue F of machinery and tools No. 4580, Crow Buildings 20 and 21, Queenhithe and Ball and Wharf lane, Upper Thames Street, London, E.C.
„ ...	The "Mechanic" improved self-acting screw cutting, sliding and surfacing, gap lathes, with 4 jawed chuck, 8 screw belt chuck, catch plate, compound pivot, slide rests, with traversing motion for self-acting, surfacing, following stay and steady rest and instantaneous reverse motion for screw cutting right and left over-head motion complete, set of spanners and change wheels, bridged gaps and bench behind for tools, centres 5″, length of bed 6″, width 7½″; between centres 4′ 3″, complete with back shaft.
„	The Twentieth Century steel river forge (style No. 401), size of hearth 18″, fan 9″, weight 90 lbs., which can be had from Messrs. Burn & Co., Limited, Calcutta.

Quantity.		Description of work.
No. 1.	...	Vice bench.
„	...	Solid bore, black staple vice, about 70 lbs.
„	...	Anvil, 2 cwts.
		Blacksmith tools.
		Lathe tools.
30 ft.	...	$1\frac{1}{2}''$ Bright M. S. shafting complete.
No. 2.	...	Loose collars $1\frac{1}{2}''$.
No. 4.	...	Plummer blocks $1\frac{1}{2}''$.
„	...	Split W. I. pulleys 12″ × 6″ wide.
		Belting leather about 200 feet of assorted widths.
No. 1.	...	Grindstone, 24″×4″, with fast and loose pulleys and tool rest, Government pattern with W. I. frames, water cistern, taps and legs.
		Erection.
„	...	$3\frac{1}{2}$ B.H.P. Hornsby oil-engine including erection, etc., complete.
		Total Rs.

A Filter Well And A Filter Trench For Quick Disposal Of Spill Water At Fountains: Plates 179 And 180.

In the above plates are illustrated the type designs Nos. 113-A, and 113-B, issued with proceedings of the Madras Sanitary Board No. 374-S., dated 19-10-1911. The specification report which accompanied these designs was as follows: In towns which possess piped water supplies and no proper drainage it has been found that the spill water from fountains forms either objectionable pools or stagnates in the road side earthen ditches. In these pools and ditches mosquitoes breed in large numbers and complaints have been made on this account alone. The spill water does not soak into the sub-soil at a sufficiently fast rate and it is necessary to devise means whereby the spill water will be immediately conveyed under the surface of the ground so as to prevent stagnation in pools and the breeding of mosquitoes. Two type designs have therefore been drawn up. The first one shows a filter well and the second a filter trench. Filter well: It is proposed that a well should be constructed, close to a public fountain, into which the spill water would pass direct through a syphon trap. The well is shown as 4 feet in diameter and 8 feet deep. The bottom portion of the steining 4 feet in height will be of well-brick in mud and the upper of the same brick in chunam mortar. The spill water will collect in this well and soak into the sub-soil. Any excess water received in the well during the day will soak away at night. The well top will be covered with stone slabs and a syphon disconnecting trap will be provided as shown to prevent any objectionable smell reaching the fountain platform. The well will be located on a favourable site in porous soil, the sub-soil water level being usually below the level of bottom of well. In such places where the well cannot be constructed close to a fountain, it will be constructed on adjoining land as near to the fountain as circumstances permit, the necessary connection being made by a pipe. Filter trench: The Sanitary Engineer has noticed at Conjeeveram that the spill water of certain fountains is led to a ditch passing the roots of cocoanut trees. Unfortunately the soakage of the water in these circumstances is not sufficient to prevent a nasty pool forming by the road side. To avoid this, a type design for a filter trench has been drawn up. In this type design it is proposed to lead the spill water from a fountain suitably located into an open jointed sub-soil pipe surrounded by broken stone, through which the soakage of the spill water into the sub-soil will be rapid. A small cistern at the beginning of the sub-soil pipe is intended for pipe cleaning purposes. As in the case of the filter well, where suitable soil does not exist near a fountain, the spill water should be led away by a stoneware or iron pipe to the nearest suitable location for the filter trench. The cost of "the Filter well" at Madras rates will be about Rs. 50 and of "the Filter Trench" Rs. 20. The following is a further note issued by the Sanitary Engineer to the Government of Madras: With reference to these two designs, the following questions have recently been brought forward: (1) What should be the nature of the soil in which the filter wells or filter trenches shewn in the two designs mentioned above can be expected to give satisfactory results? (2) As the average cost of one filter well is Rs. 50 against the average cost of Rs. 20 for a filter trench, what should be the guiding factors to determine which of these two designs should be preferred? 2. In all cases, where the sub-soil is sand, the construction of any one of the designs will be found to give satisfactory results. Where the soil is garden earth or loose earth any one of these two designs will give tolerably good results as in the case of sandy soils. These designs are unsuitable for clay and black cotton soils or where the soil is disintegrated rock. The filter well however possesses the distinct advantage of not requiring to be cleared out except at long intervals of time. 3. The filter trench design (No. 113-B) should be adopted in all cases, (1) where the soil is sand, garden earth or loose earth, (2) when the winter sub-soil water level is as high as only 2 or 3 feet below ground, and (3) where the maximum area required, *viz.*, 40′ × 3′ is available. 4. The filter well design (113-A) should be adopted (1) when the sub-soil at the depth of 4 to 8 feet below ground is sand, garden earth or loose earth, (2) when the winter sub-soil water level is at a level 8 ft. or more below ground level, (3) where

the maximum circular area of $5\frac{1}{2}$ feet diameter is available. 5. From the above it will be observed that if only the necessary space near the fountains for the filter trench is available, this design should nvariably be adopted in preference to the filter well design. 6. When proposals for providing filter trenches or filter wells near fountains are submitted, they should invariably be accompanied by (1) a statement of nature of sub-soil and winter sub-soil water level conditions at sites in which they are proposed to be constructed, (2) a statement or a general report to the effect that space at or near fountains is available, (3) and a statement of reasons for adopting filter wells (112-A) in cases where they are proposed in preference to filter trenches (113-B).

Abstract Of Quantities For A Filter Well For The Disposal Of Spill Water At Fountains: Plate 179.

Quantity.	Description of work.
129 c. ft. ...	Earthwork, excavation.
3 „ ...	Concrete, brick jelly in chunam.
45 „ ...	Brickwork in clay with well bricks.
36 „ ...	Brickwork in chunam with well bricks.
43 sq. ft. ...	$\frac{1}{2}''$ cement plastering.
8 „ ...	4" Cutstone covering slab.
No. 1 ...	4" glazed stoneware syphon trap.
„ 1 ...	4" stoneware pipe.
Sum.	4" cast iron short pipe.
„	Fixing and jointing syphon trap and pipe.
No. 1 ...	Cast iron cover including fixing for syphon trap.
Sum.	Wrought iron grating including fixing.
	Sundries.
	Total Rs.

Abstract Of Quantities For A Filter Trench For The Disposal Of Spill Water At Fountains: Plate 180.

Quantity.	Description of work.
86 c. ft. ...	Earthwork, excavation.
5 „ ...	Concrete, brick jelly in chunam.
8 „ ...	Brick in chunam.
15 sq. ft. ...	$\frac{1}{2}''$ cement plastering.
7 „ ...	$1\frac{1}{2}''$ Cuddapah slab.
41 r. ft. ...	3" sub-soil earthenware pipe.
41 „ ...	Laying 3" sub-soil earthenware pipe.
34 c. ft. ...	Broken stone filling.
Sum. ...	Wrought iron grating including fixing.
	Sundries.
	Total Rs.

An Air Valve Pit: Plate 181.

In the above plate is illustrated the type design No. 150 issued with proceedings of the Madras Sanitary Board, No. 142-S., dated 19-2-1914. The specification report which accompanied this design was as follows: To prevent obstruction to the free flow of water in water supply mains owing to the accumulation of air at summits, air valves should be fixed as shown in design. The air valves will be connected to the main by means of wrought-iron tubes of $\frac{3}{4}''$ diameter laid at a slope of 1 in 20 in the horizontal portion of their length as shown on the plan. The air valves shall be placed in pits 2′ 1″ deep, the bottom 6″ being filled with concrete, broken stone or broken brick in surkhi mortar. The side walls of the pit will be built of brick in surkhi mortar, 9″ thick and 1′ 3″ high. A weep hole 2″ × 2″ to carry away the spill water, if any, shall be provided and connected to the adjoining filter trench, 4 feet long, which will be made of 3″ stoneware pipes surrounded by broken stone. The exposed portions of the pit will be plastered with cement plaster, $\frac{1}{2}''$ thick. A cutstone seat will be provided for the air valve as shown in the plan. A cast iron surface box, as illustrated in figure 22 P, section D, page 14 of Messrs. Glenfield and Kennedy's catalogue shall be provided. A $\frac{3}{4}''$ screwdown ferrule tap together with cast iron dome shall be provided on the main, the tap and the dome being as specified in Messrs. Glenfield and Kennedy's catalogue, section G, page 7, figures E. 56 and E 115 respectively. The air valve provided with $\frac{3}{4}''$ nipple and $2\frac{1}{2}''$ diameter of ball, sha'l be similar to figure H 4, page 32, section B of Messrs. Glenfield and Kennedy's catalogue. The cost of the work will vary from Rs. 35 to 50 according to locality.

Abstract Of Quantities For An Air Valve Pit: Plate 181.

Quantity.	Description of work.
	Supply and delivery of piping required for an air valve.
5 r. ft. ...	Galvanised wrought-iron tube, $\frac{3}{4}''$ diameter.
6 No. ...	$\frac{3}{4}''$ galvanised wrought-iron tube couplings.
3 No. ...	$\frac{3}{4}''$ galvanised wrought-iron tube $\frac{1}{4}$ bends.
1 No. ...	$\frac{3}{4}''$ screwdown ferrule tap, similar to figure E 56, page 7, section G of Messrs. Glenfield and Kennedy's catalogue of 1910, with cast iron dome cover for ferrule taps similar to figure E 115 on the same page.
1 No. ...	Air valve, screwed, similar to figure H4, on page 32, section B of Messrs. Glenfield and Kennedy's catalogue of 1910, $\frac{3}{4}''$ nipple and $2\frac{1}{2}''$ diameter of ball.
1 No. ...	Cast iron surface box, figure B 22 P, page 14, section D of Messrs. Glenfield and Kennedy's catalogue of 1910.

Quantity.	Description of work.
	Fixing air valves, etc.
104 c. ft. ...	Earthwork, excavation and refilling.
3 „ ...	Concrete, broken stone in surkhi mortar.
6 „ ...	Brickwork in surkhi mortar.
10 sq. ft. ...	Plastering with cement, ½″ thick, 1 : 3.
1 No. ...	Cutstone seat including setting.
5 r. ft. ...	Laying and jointing ¾″ wrought-iron tubes with bends, coupling, etc., complete, including excavation and refilling.
1 No. ...	Fixing air valve to ¾″ tube and making junction with main, fixing ferrule and dome cover.
1 No. ...	Fixing cast iron surface box.
	Broken stone filling at weep hole.
	Sundries.
	Total Rs.

A House Connection With ¾ Inch Water Meter : Plate 182.

In the above plate is illustrated the type design No. 152, issued with proceedings of the Madras Sanitary Board, No. 174 S. 5., dated 4-3-1914. The specification report which accompanied this design was as follows: General: The house connection shall consist of (1) a length of ¾-inch galvanised wrought iron service pipe and connections complete, (2) a masonry chamber to locate the stop cock and meter and measuring 3′ 6″ × 3′ with a wrought iron cover plate and (3) a ¾-inch water meter with all accessories complete. The dispositions of the pipe, stop cock, meter and pit shall be as shown in the design. 2. Service pipe: This shall be ¾-inch size. The main in the street shall be tapped and a straight ferrule inserted and connected with couplings and back nuts to a suitable length of ¾-inch galvanised wrought iron pipe, on which the stop cock and meter shall be fixed, as it crosses the pit. The piping shall then be continued till it reaches the house, crossing the road side drain on its way as shown in the design. 3. Meter pit: This shall measure 2′ × 1′ 6″ inside and shall be located six inches from the outer edge of the roadside drain towards the centre of the road. The excavation for the pit shall be one foot four inches deep, of which the first six inches shall be filled in with concrete, broken brick in chunam and the remainder shall be built with brick in chunam, 9 inches thick. A cutstone coping, 9 inches broad and 4 inches deep shall be built over this brick masonry. A suitable slope at the outer edge and a recess all round the inner edge to receive a cover shall be formed on the top of the coping. The interior of the pit including floor shall be plastered with best Portland cement mortar (2 to 1), half an inch thick. There shall be a wrought iron cover plate with necessary locking arrangement as shown in the design. 4. Meter: This shall be Tylor's patent ¾-inch rotary water meter, or other approved type, and shall include strainer, unions for ¾-inch galvanised wrought iron tubing with necessary bolts, nuts, washers, etc., complete, similar to illustration on page 243 of Messrs. Tylor & Son's catalogue, 18th edition.

Abstract Of Quantities For A House Connection With ¾-Inch Water Meter : Plate 182.

Quantity.	Description of work.
63 c. ft. ...	Earthwork, excavation and refilling.
5 „ ...	Concrete, broken bricks in chunam.
5 „ ...	Brickwork in chunam.
10 sq. ft. ...	Plastering with cement, ½″ thick, 1 : 2.
3 c. ft. ...	Cutstone work.
	Broken stone filling.
	¼″ wrought iron plate cover with chain, rag bolts including locking arrangement, fixing, complete.
	6″ square slab under meter including setting.
10 r. ft. ...	¾″ wrought iron tube, galvanised.
7 No. ...	¾″ wrought iron coupling, galvanised.
1 „ ...	¾″ stop cock with female screwed ends as per fig. F 15, sec. G, page 18 of Messrs. Glenfield & Kennedy's Catalogue.
1 „ ...	¾″ rotary water meter with strainer and unions as on page 243 of Messrs. Tylor & Son's Catalogue.
1 „ ...	¾″ straight ferrule as per fig. E 14, sec. G, page 30 of Messrs. Glenfield & Kennedy's Catalogue.
1 „ ...	Back nut including fixing.
1 „ ...	Fixing ¾″ stop cock.
1 „ ...	Fixing ¾″ water meter.
	Fixing ¾″ straight ferrule including tapping, etc.
11 r. ft. ...	Laying and jointing ¾″ wrought iron tube including bends, etc.
	Sundries.
	Total Rs.

DRAINAGE: INTRODUCTION.

Past Progress In Madras Presidency.

The available funds of Local Bodies in the past have not been sufficient to introduce simultaneously both water supply and drainage works. Water supply works are first introduced while drainage works are deferred until finances improve. Of course, the Local Bodies carry out petty improvements to road side drains. In the whole of the Madras Presidency, there are only two towns provided with modern sewerage systems, *viz.*, the City of Madras and Ootacamund Municipality. In this connection, I would again quote the following further extracts from the paper, read by Mr. Hutton at the 1911 'All India Sanitary Conference.' "The drainage system in Madras consists in the division of the City into a number of sections each with a pumping station, to the pump well of which sullage gravitates through stoneware pipe sewers. The sullage is pumped out of the pump wells by steam plant in some cases and by oil engines and centrifugal pumps in others and is forced through a cast iron rising main of a total length of 9 miles to a sewage farm located on the sandy area north of the City and adjoining the sea-shore. The most populous section of the town is drained by open drains and two intercepting sewers to a pumping station where the sullage is pumped through an independent rising main to the same sewage farm. The pipe drainage of another section of the City is now under construction. The soil of the sewage farm is almost pure sea sand, and the farm which extends to 150 acres has from the first been highly successful in disposing of the sullage pumped on to the farm. The crop grown on the farm is bariali grass which is made into hay and sold as fodder for the feeding of horses. The farm yields a revenue of Rs. 30,000 per annum or Rs. 200 per acre. This large yield is due to the porous nature of the soil, the high average temperature of the atmosphere, and the fertilizing nature of the sullage. The quantity of sullage pumped on to the farm per acre appears to be 30,000 gallons, and this comparatively large quantity is satisfactorily disposed of as the sullage is comparatively weak and the sandy soil of the farm is capable of absorbing a large amount of liquid. In the future the sullage will become stronger in composition and it may then be necessary to add septic tanks to the system. The second drainage work carried out in Madras on modern lines is that at Ootacamund on the Nilgiri Hills. In this town a system of 6 and 9 inch stoneware branch sewers on the separate system was laid down connecting up all the important inhabited parts. Owing to the steep location of the town it was necessary in many cases to introduce drop manholes on the lines of branch sewers and in other cases to use cast iron pipes instead of the usual stoneware pipes. The following were the limiting gradients adopted for the stoneware pipe sewers:

			Full and half full velocity.
		6" sewers.	
Minimum	...	1 in 100	$2\frac{1}{2}$ feet per second.
Maximum	...	1 in 40	4 ,,
		9" sewers.	
Minimum	...	1 in 190	$2\frac{1}{2}$ feet per second.
Maximum	...	1 in 76	4 ,,

The beginning of each 6 inch branch sewer was provided with Field's flushing syphons of 90 gallons capacity and the system was ventilated with air inlets alternating with 4 inch ventilating shaft outlets, 20 feet high at every manhole not more than 300 feet apart. The distance between ventilating shafts was therefore not more than 600 feet. The branch sewers discharge into an old 12 inches cast iron main sewer laid along the margin of the Ootacamund lake. Owing to this location the main sewer was not found to be as satisfactory as it should have been. The gradient averages 1 in 903 and it is now contemplated to lay down a new 18 inches cast iron main sewer with a grade of 1 in 414. The present 12 inch main sewer is flushed with stream water and also with sewage by means of three 5,000 gallon masonry flush tanks which are filled from high level branch sewers. The public latrines have been rebuilt as water carriage flushing latrines and dumping pits are being provided as pail depots. A night soil shoot has been built near the septic tank and is in daily use with satisfactory results to the conservancy of the town. The sewage is disposed of by means of a septic tank of 24 hours' capacity, or 2,00,000 gallons, and a sewage farm of 14 acres. The soil of this farm is more or less of a heavy nature and it has consequently been provided with sub-soil drains 33 feet apart discharging into an effluent channel which runs along one side of the farm. The net revenue from the produce of the farm, principally grass and green oats, is nearly Rs. 100 per acre per annum and the disposal works have satisfactorily met the problem of turning the raw sewage into an inoffensive effluent. There

are altogether in the town 1,423 house connections most of which have been provided for the Indian houses at the cost of the scheme. It was intended that the owners of European houses, in proximity to the sewers, should put in house connections as soon as the system was laid down. This, they have not done up to date, apparently in the hope that Government or the Municipal Council would construct the connections and debit the cost to the estimate for the drainage works. The works were practically completed three or four years ago and ever since they were projected they have been subjected to a large amount of public criticism so that the council hesitated to become responsible for them. This criticism re-acted on the house owners themselves who found that visitors, not understanding the real situation, preferred to go to other hill stations. The criticisms, if not actually started, were certainly fostered by newspapers which rarely lost a chance of deriding modern drainage works as carried out at Ootacamund. If there was unusually heavy rain of say 2 inches in the hour and the old main sewer surplused, this was held up as conclusive proof of the failure of the works. As the system was only intended to carry away rainfall up to 1 inch per day which means a dilution of sewage over six times the dry weather flow, the old main sewer necessarily surplused. Gradually as minor mistakes in construction were rectified, the agitation subsided with the result that the Municipal Council after three years' experience of the working of the drainage system have voluntarily proposed to take over and have actually taken over charge of the works. This change of opinion has been assisted by the discovery that, while other hill stations were suffering from unhealthiness, the public health of Ootacamund had apparently improved of late years. In this connection I should like to take this opportunity of quoting from the reported speech of His Excellency Sir Arthur Lawley in reply to a farewell address from the Ootacamund Municipal Council presented on the 24th October 1911 in which the drainage scheme was referred to: "Now Ootacamund resembles many other good things in that she is not exempt from criticism. And I am afraid that criticism is sometimes tempted in its desire for effect to dispense with the companionship of truth. I was reading the other day some essays on politics by a distinguished Canadian writer, and the opening words of one of his essays runs: It requires about 33 years to remove a false impression from the public mind and about the same length of time to replace it by a correct one. Twice 33 is 66. Being of a sanguine temperament, I hope that it will be less than 66 years before the public mind will be disabused of the quite erroneous idea which has lately been assiduously promulgated in the Press, and is to me quite incomprehensible, that the sanitation and the drainage and the health of Ootacamund are in very parlous plight. I am no expert in sanitary matters, but I have made it my business to obtain the opinions of those who are, and who have carefully investigated the plans of the Ootacamund drainage scheme, and the manner in which the designs have been carried out, and they are unanimous in assuring me that the scheme as a whole is admirably conceived and has been so far most efficiently carried out. Defects of detail, of course, there will be, as there must be in every scheme of this nature, but these, as they come into evidence, are being corrected and I am confident that when complete you will have a most valuable asset conducing to the credit of those who introduced it and the great benefit of those whom it serves. Various works of sanitation have been completed, others are in progress and others here, as in every other town in the world, are waiting to be taken in hand. Meanwhile it is satisfactory to know that you can say and say with truth that public health is excellent."

New Proposals.

"One most important mufassal town to be provided with an up-to-date drainage system is Madura with a present population of 1,36,000. This town occupies a flat site principally on the right bank of the river Vaigai which enters the sea near the island of Rameswaram after a course below Madura of about 80 miles. A complete drainage scheme of pipe sewers on the separate system has been drawn up for this town, the estimated cost being 21 lakhs of rupees. This scheme will, when constructed, serve a population of 1,71,460 so that the cost per head of present population will be Rs. 18 and of future population Rs. 13. Owing to the flat location of the town the area to be drained, 931 acres, has been divided into six sections. Each section is provided with a pump well so as to provide sufficient gradient for the sewers. Five of the sections pump into the heads of main sewers through independent rising mains, and these main sewers connect with masonry conduits which finally discharge the sewage through a screening chamber into the pump well of the main pumping station. Each of the five smaller pumping stations are provided with oil-engines and centrifugal pumps, but the main pumping station is provided with direct acting steam plant which will pump the whole sewage of the city through a 24-inch cast iron rising main 5 miles in length to a sewage farm of 186 acres. The soil at the site of this farm is red earth to a depth of 3 or 4 feet overlying gravel. It is proposed to utilise the sewage, pumped on to the farm, for growing sugarcane and it is hoped to realise a net revenue of Rs. 250 per acre which amount is

based on local opinion and on the Poona experiments. The sewers are designed to carry ½ inch rainfall per day per house over an area of 1,000 square feet in addition to the sullage based on the population of each house which has been taken as composed of 6 people, and the water supply which is 15 gallons per head per day. In addition to this provision for rain water, the limiting length of a 6-inch sewer has been made 300 feet and beyond this length for the 6-inch sewer, a 9-inch sewer has been substituted but to be laid with the 6-inch sewer gradient. On similar principles a 12-inch sewer has been substituted for a 9-inch and a 15-inch for a 12-inch. These increased sizes of sewers are designed to be laid at the gradient of the next smaller size. The object of this proposal is to have increased provision for carrying off heavy rain which may fall within a short time. The result of increasing the size of sewers as mentioned above means a slight lowering of the velocity of the sewage, but this diminution is considered so small as not to practically affect the self-cleansing velocities in the sewers when half full. The following are the gradients adopted in the scheme:

Size.	Minimum.	Sewage velocity when pipe is ½ full or full per second.	Maximum.	Sewage velocity when pipe is ½ full or full per second.
4 inches ...	1 in 52.	2½ feet.	1 in 21.	4 feet.
6 " ...	1 in 100.	Do.	1 in 40.	Do.
9 " ...	1 in 190.	Do.	1 in 76.	Do.
12 " ...	1 in 295	Do.	1 in 120.	Do.
15 " ...	1 in 415	Do.	1 in 165.	Do.

The velocities have been calculated from Kutter's formula with a co-efficient of ·013. If other formulæ are used, the velocities in the smaller sizes will be increased by 25 per cent. At least the minimum gradients are provided in the scheme except in the cases of some short lengths of unimportant sewers where it was found impossible to carry out rigidly the rules for gradients stated above. Such exceptions will occur in every practical scheme of drainage and if efficient flushing is provided the unimportant exceptions can be accepted. The greatest depths of sewers generally, except when a short length of ridge has to be passed through, has been fixed at 13 feet, that being the lowest sub-soil summer water level in the sandy sub-soil of the city. The main section of the system will be ventilated by air inlets at the head of branch sewers, the only outlet being an extracting fan at the main pumping station where the foul air will be purified in a coke tower. The other five independent sections will be ventilated by air inlets and ventilating shafts as in the Ootacamund scheme. Masonry flush tanks of 500 gallons capacity and in some cases, Field's automatic flush tanks, are provided in the scheme at the heads of all branch sewers and wherever possible these tanks are filled with spill water from public fountains. Where piped water is not expected to be available, 4 feet wells provided with semi-rotary pump are proposed to be sunk in the sandy sub-soil of the streets so as to provide the necessary water for flushing purposes. The latrines of the town will be converted into flushing latrines and the 20 dumping pits or pail depots proposed will improve the existing conservancy arrangements. The main pumping station is designed to be capable of pumping three times the dry weather flow to the sewage farm, the remainder of the rain water and sullage being surplused from the main conduit into an irrigation channel which will lead away the surplus sullage to paddy fields. The estimated annual pumping charges up to 1,927 are estimated at Rs. 49,630, out of which amount Rs. 37,500 is expected to be recouped by net income from the growing of sugarcane on the sewage farm, so that the net working cost of the scheme is estimated at Rs. 12,130. The scheme as described is now under construction. A scheme for the drainage of the town of Vellore, population 40,000, has been drawn up and is also under construction. This scheme provides for open oval shaped masonry drains, on each side of streets and conservancy lanes. These drains have been designed to be capable of discharging ½ an inch of rainfall per hour over the area draining into them. The drains provided are intended to be constructed with a concrete floor and side walls of brick in lime mortar with cutstone copings. The inside of the drains will be plastered with Portland cement to an oval shape. It is found cheaper in the end to use Portland cement for this plastering rather than use ordinary or kankar lime mortar the lasting properties of the latter not being good when used in sullage drains. The scheme further provides for pumping the sullage up to three times the dry weather flow on to an underdrained sewage farm of 44 acres on which it is proposed to grow crops of sugarcane. The estimated cost of the scheme is Rs. 3,67,764 which is at the rate of Rs. 9 per head of present population. Drainage schemes for the towns of Trichinopoly, population 1,20,000 and Negapatam, population 58,000, Nellore, population 33,000 and Ellore, population 38,000 are at present being drawn up, and are expected to be under execution shortly. In addition to these towns drainage schemes for six other towns have been investigated and plans and estimates will be drawn up shortly. Many of these schemes are principally for financial reasons, on the open drainage combined system. The cost of drainage works in Madras can be approximately stated to be as follows in terms of present population.

	Per head. Rs.
Pipe sewerage schemes involving sectional pumping by oil and steam plant with cast iron rising mains, septic tanks and sewage farm	18
Open drainage schemes with intercepting pipe sewers, oil or steam plant, cast iron rising mains, septic tanks and a sewage farm	9
Open drainage schemes without pumping and discharge of crude sewage into the sea or tidal river	6

In many towns small sewage farms for disposal of sullage from local areas have been laid out. The largest sewage farm in use in the whole Presidency is that belonging to the City of Madras. At this farm no septic tanks are in use or required at present although their construction will probably be found necessary in the future. The soil at this farm being sea sand it forms an ideal means for sewage disposal. At Ootacamund where there is a septic tank the sewage farm in use is composed of heavy soil which requires to be underdrained. In such cases where light and open soil is absent excellent results from the growing of grass for fodder may be achieved by top dressing the site of a farm with one or two feet of street rubbish so as to form a porous soil in which roots may spread easily and not be stunted in growth as in the case of grass grown on heavy or loamy soil. In this connection it may be remarked that in the case of certain sewage farms in Madras City, now abandoned, as they were located too near dwellings, the growth of grass was phenomenal. These farms were located on sites which were in former times swamps or low ground but subsequently reclaimed by the dumping of street rubbish which was carted to the sites in conservancy carts. Our experience in Madras is in favour of sewage disposal by the use of septic tanks and a sewage farm. The septic tank should be designed in such a way that sludge may be periodically removed on opening a valve thus causing the minimum of interference with the working of the tanks. What appears to be a cheap and suitable form of septic tank is a tank of triangular wedge section constructed with apex downwards, a slotted pipe being placed at the point of the wedge so as to receive the sludge which will be momentarily deposited. This sludge can be removed by the opening of a valve placed on the pipe the requisite discharge head being provided by the liquid in the tank. Tanks of this type can be cheaply constructed as a simple excavation, the sides to be puddled with clay and pitched with stone. They may be left either open, or closed by a light corrugated iron roof."

DRAINAGE: DESCRIPTION AND COMPARISON OF THE VARIOUS SYSTEMS: GENERAL PRINCIPLES GOVERNING THEIR DESIGN: VARIOUS METHODS OF HOUSE AND STREET DRAINAGE: DATA FOR PRELIMINARY PROPOSALS: KNOWLEDGE OF METHODS FOR THE ROUGH DETERMINATION OF AN OPEN DRAIN, CHANNEL, CLOSED PIPE AND SEWER.

Various Systems.

'Conservancy' and 'Water Carriage' systems are the two systems, by which the removal of the sewage of towns consisting of excreta, liquid household sullage, and trade waste is carried out. The water carriage method is again sub-divided under two heads, the 'combined' system and the 'separate system.' All sewage matter, rain water from roofs, roads, yards, etc., are conveyed by one set of sewers in the combined system. In the separate system, two sets of sewers are laid, one to convey foul matters and liquid and another set of sewers of large sizes to convey storm water direct to some nearest channels or water courses. For practical purposes, the systems of drainage may be classed as follows: 1. Open drainage. 2. Open drainage and closed intercepting sewers combined. 3. Closed sewerage scheme. In the case of open drainage schemes, the works usually comprise the construction of masonry oval shaped drains of sections shown in plates 194 and 195 of sizes capable of carrying half inch rainfall per hour with suitable available gradients and disposal works. In the case of the combined system of open drains and closed intercepting sewers, the works comprise the construction of oval masonry drains in streets with intercepting sewers of sizes to carry the sewage only and disposal works. In closed sewerage schemes, the works comprise the laying of sewers in streets with intercepting sewers and disposal works.

Necessity For Immediate And Complete Removal Of House Drainage.

There is, no doubt, that ignorance still prevails even among the educated public regarding the absolute necessity for the immediate and thorough removal of all fluid refuse from houses. It is therefore not surprising that the uneducated masses do not trouble themselves with the question of house drainage. It is essentially the first duty of a Sanitary Inspector to educate the masses in the importance of proper methods for the removal from houses of all liquid refuse immediately and thoroughly. The first consideration as regards the methods for sewage removal is that sewage is conveyed away from houses immediately and thoroughly. Sewage, when fresh, is comparatively harmless. If provision is not made for its immediate and thorough removal, nuisances arise by decomposition or putrefaction that is by change brought about by the splitting up of dead organic matter into its simpler elements as minute living germs or bacteria, ever present in sewage and air, which multiply with enormous rapidity, attack all dead organic matter until complete dissolution of the material is accomplished. This process is termed fermentation. During the time when putrefaction is taking place, foul gases and discharge of fœtid organic matter contaminating the atmosphere and taxing to a great extent the purifying effect of the atmospheric oxygen seriously affecting the health of the inhabitants, result. As such nuisance favours the extension of infectious diseases, it is essential that all sewage should be disposed of promptly and thoroughly and any method of sewage removal should comply with these first essentials.

Open Drainage.

This system, as already explained, consists of the construction of oval masonry street drains, discharging the sewage either through open masonry intercepting drains or through closed intercepting drains at site of outfall works. This system can be considered as only a palliative one if the more up to date closed sewerage system cannot be afforded by a Local Body with available funds at present or in the future within a reasonable time. There is no doubt that considerable improvement in the sanitation of a place can be forecast by the introduction of an open drainage system avoiding as far as possible the usual stagnation of sullage near houses, as at present. It must however be admitted that a closed sewerage system is not only a more efficient system but also possesses the advantage that the sewage is conveyed in a manner out of sight of individuals and also avoids the breeding of flies and mosquitoes and pollution of the atmosphere.

Form Of Section Of Street Drains.

Many forms have been proposed and adopted but when it is considered that the drains have to

carry at one time sewage, and at another the sewage mixed with large quantities of storm water, it is evident that the section should be oval to permit of varying discharges. It is unnecessary to discuss here the different forms of sections. It will suffice, if it is stated that the section of drain which has given satisfactory results in actual practice is the new egg-shaped form shown in plates 194 and 195. In this section, the radius of bottom of invert is $\frac{1}{8}$ the depth of the drain and the radius of the side above the invert is $1\frac{1}{3}$ the depth.

Sizes Of Open Drains.

The open drains constructed in streets should be designed of sizes capable of carrying the storm water from their drainage areas at the rate of half inch per hour. The sewage of the population is a small fraction of this provision and need not therefore be taken into consideration in determining the sizes of open drains. The carrying capacities of open drains calculated by Kutter's formula

$$\sqrt{RS}$$

are given in the following table.

Size of open drain in inches.	Fall $\frac{1}{\text{over}}$	Velocity in feet per second.	Discharge in gallons per minute.	Area in square feet that can be drained allowing for $\frac{1}{2}$ inch rain per hour.
6	25	4·93	334	77,157
6	50	3·48	236	54,477
6	75	2·84	192	44,451
6	100	2·46	166	38,484
6	150	2·00	136	31,383
6	200	1·73	117	27,144
6	250	1·55	105	24,255
6	300	1·41	95	22,104
6	350	1·30	88	20,448
6	400	1·22	82	19,107
6	450	1·15	77	17,991
6	500	1·09	73	17,064
6	550	1·03	70	16,227
6	600	0·99	67	15,570
6	650	0·95	64	14,904
6	700	0·91	62	14,337
6	750	0·88	59	13,842
6	800	0·85	57	13,383
6	850	0·82	56	12,960
6	900	0·80	54	12,582
6	950	0·78	53	12,240
6	1,000	0·76	51	11,907
6	1,050	0·74	50	11,601
6	1,100	0·72	49	11,331
6	1,150	0·70	47	11,061
6	1,200	0·69	46	10,818
6	1,250	0·67	45	10,593
6	1,350	0·65	44	10,170
6	1,400	0·63	43	9,981
6	1,450	0·62	42	9,801
6	1,500	0·61	41	9,612
6	1,550	0·60	40	9,459
6	1,600	0·59	40	9,306
6	1,650	0·58	39	9,144
9	25	6·79	1,032	2,38,149
9	50	4·79	728	1,68,219
9	75	3·91	594	1,37,286
9	100	3·38	515	1,18,881
9	150	2·76	420	96,939
9	200	2·39	363	83,808
9	250	2·13	324	74,907
9	300	1·94	296	68,337
9	350	1·80	274	63,243
9	400	1·68	256	59,094
9	450	1·58	241	55,638
9	500	1·50	228	52,704
9	550	1·43	217	50,193
9	600	1·36	207	47,952
9	650	1·31	199	46,134
9	700	1·26	192	44,325
9	750	1·22	185	42,849
9	800	1·18	179	41,472
9	850	1·14	174	40,176
9	900	1·11	168	38,961
9	950	1·08	164	37,926
9	1,000	1·05	159	36,891
9	1,050	1·02	155	35,937
9	1,100	1·00	152	35,073
9	1,150	0·97	148	34,299
9	1,200	0·95	145	33,525
9	1,250	0·93	142	32,832
9	1,300	0·91	139	32,220
9	1,350	0·90	137	31,617
9	1,400	0·88	134	30,924
9	1,450	0·86	131	30,411
9	1,500	0·85	129	29,808
9	1,550	0·83	126	29,286
9	1,600	0·82	125	28,854
9	1,650	0·80	122	28,341
9	1,700	0·79	120	27,909
12	25	8·46	2,287	5,27,814
12	50	5·97	1,615	3,72,816
12	75	4·87	1,318	3,04,245
12	100	4·22	1,141	2,63,340
12	150	3·44	930	2,14,785
12	200	2·98	805	1,85,931
12	250	2·66	719	1,66,140
12	300	2·42	656	1,51,542
12	350	2·25	609	1,40,742
12	400	2·10	567	1,30,977
12	450	1·97	535	1,23,462
12	500	1·87	506	1,16,982
12	550	1·78	482	1,11,366
12	600	1·70	461	1,06,524
12	650	1·63	442	1,02,204
12	700	1·67	426	98,496
12	750	1·52	411	95,040
12	800	1·47	398	91,926
12	850	1·42	386	89,163
12	900	1·38	375	86,571
12	950	1·34	364	84,150
12	1,000	1·31	355	81,990

Size of open drain in inches.	Fall $\frac{1}{\text{over.}}$	Velocity in feet per second.	Discharge in gallons per minute.	Area in square feet that can be drained allowing for ½ inch rain per hour.
12	1,050	1·28	345	79,830
12	1,100	1·25	338	78,012
12	1,150	1·22	330	76,208
12	1,200	1·19	322	74,475
12	1,250	1·16	315	72,918
12	1,300	1·14	309	71,451
12	1,350	1·12	304	70,155
12	1,400	1·10	298	68,778
12	1,450	1·08	292	67,563
12	1,500	1·06	287	66,348
12	1,550	1·04	282	65,232
12	1,600	1·02	277	64,107
12	1,650	1·01	272	62,982
12	1,700	0·99	269	62,208
15	25	10·02	4,236	9,77,702
15	50	7·07	2,992	6,90,507
15	75	5·77	2,441	5,63,499
15	100	5·00	2,114	4,87,899
15	150	4·08	1,724	3,98,044
15	200	3·53	1,492	3,44,391
15	250	3·15	1,333	3,07,841
15	300	2·87	1,216	2,80,800
15	350	2·66	1,125	2,59,804
15	400	2·49	1,052	2,42,870
15	450	2·34	991	2,28,787
15	500	2·22	939	2,16,863
15	550	2·11	895	2,06,584
15	600	2·02	855	1,97,511
15	650	1·94	822	1,89,784
15	700	1·87	791	1,82,564
15	750	1·80	764	1,76,342
15	800	1·74	739	1,70,552
15	850	1·69	716	1,65,369
15	900	1·64	699	1,60,615
15	950	1·60	676	1,56,210
15	1,000	1·55	658	1,52,063
15	1,050	1·52	642	1,48,262
15	1,100	1·48	627	1,44,720
15	1,150	1·45	612	1,41,436
15	1,200	1·41	599	1,38,411
15	1,250	1.38	587	1,35,475
15	1,300	1·36	575	1,32,710
15	1,350	1·33	564	1,30,205
15	1,400	1·31	553	1,27,784
15	1,450	1·28	543	1,25,450
15	1,500	1·26	533	1,23,120
15	1,550	1·24	524	1,21,045
15	1,600	1·22	515	1,19,058
15	1,650	1·20	507	1,17,157
15	1,700	1·18	499	1,15,343
18	25	11·48	6,989	16,12,915
18	50	8·11	4,936	11,39,270
18	75	6·62	4,029	9,29,836
18	100	5·73	3,488	8,04,988
18	150	4·67	2,846	6,56,898
18	200	4·04	2,437	5,62,412
18	250	3·61	2,201	5,08,032
18	300	3·30	2,008	4,63,534
18	350	3·05	1,858	4,28,880
18	400	2·85	1,736	4,00,809
18	450	2·69	1,636	3,77,654
18	500	2·55	1,551	3,58,126
18	550	2·42	1,477	3,41,019
18	600	2·31	1,413	3,26,160
18	650	2·23	1,357	3,13,200
18	700	2·14	1,307	3,01,707
18	750	2·07	1,261	2,91,168
18	800	2·00	1,220	2,81,751
18	850	1·94	1,183	2,73,196
18	900	1·89	1,149	2,65,334
18	950	1·83	1,118	2,58,076
18	1,000	1·78	1,088	2,51,165
18	1,050	1·74	1,061	2,44,943
18	1,100	1·70	1,036	2,39,240
18	1,150	1·66	1,013	2,33,884
18	1,200	1·62	991	2,28,701
18	1,250	1·59	970	2,23,948
18	1,300	1·56	950	2,19,455
18	1,350	1·53	932	2,15,222
18	1,400	1·50	915	2,11,334
18	1,450	1·47	898	2,07,445
18	1,500	1·45	882	2,03,645
18	1,550	1·42	867	2,00,188
18	1,600	1·40	853	1,96,991
18	1,650	1·38	839	1,93,708
18	1,700	1·35	826	1,90,770
21	25	12·87	10,661	24,60,413
21	50	9·09	7,531	17,38,022
21	75	7·42	6,147	14,18,601
21	100	6·42	5,322	12,28,262
21	150	5·24	4,342	10,02,152
21	200	4·53	3,758	8,67,284
21	250	4·05	3,359	7,75,352
21	300	3·70	3,064	7,07,271
21	350	3·42	2,836	6,54,565
21	400	3·20	2,651	6,11,797
21	450	3·01	2,498	5,76,547
21	500	2·86	2,368	5,46,565
21	550	2·72	2,255	5,20,387
21	600	2·60	2,158	4,98,009
21	650	2·50	2,071	4,78,138
21	700	2·41	1,995	4,60,512
21	750	2·32	1,926	4,44,528
21	800	2·25	1,864	4,30,357
21	850	2·18	1,807	4,17,224
21	900	2·12	1,755	4,05,129
21	950	2·06	1,708	3,94,241
21	1,000	2·00	1,662	3,83,702
21	1,050	1·95	1,621	3,74,197
21	1,100	1·91	1,583	3,65,384
21	1,150	1·86	1,547	3,57,177
21	1,200	1·82	1,514	3,49,486
21	1,250	1·79	1,482	3,42,058
21	1,300	1·75	1,453	3,35,405
21	1,350	1·72	1,425	3,28,925
21	1,400	1·68	1,398	3,22,788
21	1,450	1·65	1,373	3,17,001
21	1,500	1·62	1,348	3,11,126
21	1,550	1·60	1,325	3,05,942
21	1,600	1·57	1,304	3,01,015
21	1,650	1·55	1,283	2,96,178
21	1,700	1·52	1,263	2,91,600
24	25	14·18	15,341	35,40,413
24	50	10·02	10,837	25,01,019
24	75	8·17	8,846	20,41,544
24	100	7·08	7,659	17,67,485

Size of open drain in inches.	Fall 1 over.	Velocity in feet per second.	Discharge in gallons per minute.	Area in square feet that can be drained allowing for ½ inch rain per hour.
24	150	5·77	6,250	14,42,446
24	200	5·00	5,409	12,48,307
24	250	4·47	4,835	11,15,942
24	300	4·07	4,411	10,18,138
24	350	3·77	4,082	9,42,018
24	400	3·52	3,817	8,80,846
24	450	3·32	3,596	8,29,957
24	500	3·15	3,410	7,87,017
24	550	3·00	3.247	7,49,347
24	600	2·87	3,108	7,17.378
24	650	2·75	2,983	6,88,606
24	700	2·65	2,873	6,63,205
24	750	2·56	2,774	6,40,223
24	800	2·48	2,685	6,19,747
24	850	2·40	2,603	6,00,824
24	900	2·33	2,528	5,83,544
24	950	2·27	2,459	5,67,561
24	1,000	2·21	2,394	5,52,614
24	1,050	2·16	2,336	5,39,134
24	1,100	2·13	2,280	5,26,348
24	1,150	2·06	2,230	5,14,685
24	1,200	2·01	2,181	5,03,453
24	1,250	1·97	2,135	4,92,911
24	1,300	1·93	2,094	4,83,235
24	1,350	1·89	2,053	4,73,988
24	1,400	1·86	2,016	4,65,263
24	1,450	1·83	1,979	4,56,796
24	1,500	1·79	1,943	4,48,502
24	1,550	1·76	1,912	4,41,245
24	1,600	1·73	1,879	4,33,814
24	1,650	1·71	1,850	4,27,076
24	1,700	1·68	1,828	4,20,598

The sectional areas and hydraulic mean depths of the different sizes of open drains shown in plates 194 and 195 are shown in the following table:

Size of drain.	Sectional area.	Hydraulic mean depth.
Inches.	sq. ft.	feet.
6	·1806	·1537
9	·4063	·2306
12	·7223	·3074
15	1·1287	·3843
18	1·6253	·4611
21	2·2122	·5380
24	2·8894	·6148
27	3·6568	·6917
30	4·5146	·7686

The quantities of work of different sizes of open drain as shown in plate 194 for a length of 100 feet in each case, are as follows: 6 inch open drain: 266 cub. ft. Earthwork; 106 cub. ft. Concrete, brick jelly in mortar; 76 cub. ft. Brick in mortar; 60 cub. ft. Brick on edge; 129 sq. ft. Plastering with cement, ¾ inch thick; 150 sq. ft. Pointing with cement. 9 inch open drain: 356 cub. ft. Earthwork; 119 cub. ft. Concrete, brick jelly in mortar; 131 cub. ft. Brick in mortar; 58 cub. ft. Brick on edge; 187 sq. ft. Plastering with cement, ¾ inch thick; 150 sq. ft. Pointing with cement. 12 inch open drain: 459 cub. ft. Earthwork; 131 cub. ft. Concrete, brick jelly in mortar; 193 cub. ft. Brick in mortar; 57 cub. ft. Brick on edge; 246 sq. ft. Plastering with cement, ¾ inch thick; 150 sq. ft. Pointing with cement. 15 inch open drain: 575 cub. ft. Earthwork; 144 cub. ft. Concrete, brick jelly in mortar; 263 cub. ft. Brick in mortar; 57 cub. ft. Brick on edge; 304 sq. ft. Plastering with cement, ¾ inch thick; 150 sq. ft. Pointing with cement. 18 inch open drain: 703 cub. ft. Earthwork; 156 cub. ft. Concrete, brick jelly in mortar; 333 cub. ft. Brick in mortar; 57 cub. ft. Brick on edge; 383 sq. ft. Plastering with cement, ¾ inch thick; 150 sq. ft. Pointing with cement. 21 inch open drain: 844 cub. ft. Earthwork; 169 cub. ft. Concrete, brick jelly in mortar; 413 cub. ft. Brick in mortar; 57 cub. ft. Brick on edge; 441 sq. ft. Plastering with cement, ¾ inch thick; 150 sq. ft. Pointing with cement. 24 inch open drain: 997 cub. ft. Earthwork; 181 cub. ft. Concrete, brick jelly in mortar; 496 cub. ft. Brick in mortar; 57 cub. ft. Brick on edge; 504 sq. ft. Plastering with cement, ¾ inch thick; 150 sq. ft. Pointing with cement.

Removable Drain Coverings (Unsuited For Wheeled Traffic): Plate 210.

In the above plate is illustrated the type design No. 102 issued with proceedings of the Madras Sanitary Board No. 151-S., dated 30-4-1907. The specification report which accompanied this design was as follows: Two designs have been prepared; one shows a Cuddapah slab drain covering and the other an iron grid. It is proposed that the Cuddapah slab covering should be used as an entrance to dwelling houses and the iron grid covering as a continuation if required or in front of shops. In the latter position the length of Cuddapah slab covering would be so great as to be objectionable. Accordingly in front of shops only iron grids will be used and in no case should a Cuddapah slab covering be allowed for a longer continuous length than 4 feet. Cuddapah slab covering: On both sides of the top of a drain at the place where it is proposed to permit a covering being laid down a cutstone will be fixed 9″ × 4″ × 4′ long. The object of the cutstone is to prevent damage to the masonry of the drain each time the covering is removed. On the top of these cutstones will be laid a Cuddapah slab, 2 inches thick, to form the drain covering. Care will have to be taken to see that the slab lies firmly on the cutstone supports

which should be evenly dressed on their top surface. Grid covering: Similar cutstones to that required for the slab covering will be required in this case also. These cutstones will have cut on their top surfaces, grooves 2 feet apart to form bearings for an iron grid. The grooves must be of sufficient depth so that the flat bar forming the cheek of the grid is flush with the top of the cutstone. This grid will be made of ½ inch iron bars riveted to $1\frac{1}{2}'' \times \frac{1}{4}''$ cheeks. The grid will be made up in 2 feet lengths for convenience in handling and for strength. The following is a statement of cost at Madras rates of the two kinds of covering taking each covering as 4 feet in length:

	Cuddapah slabs. RS.	A.	P.	Iron grid. RS.	A.	P.
6" drain	5	1	6	6	1	0
9" "	5	4	0	6	13	0
12" "	5	6	6	7	7	6
15" "	5	9	0	8	4	0
18" "	5	11	6	8	12	0
21" "	5	14	0	9	10	0
24" "	6	1	0	10	3	0

Abstract Of Quantities For Removable Drain Coverings (Unsuited For Wheeled Traffic): Plate 210.

Quantity.	Description of work.
	Cuddapah slab removable drain covering 4' long for a 6" open drain.
2 c. ft. ...	Granite stone.
6 sq. ft. ...	Slab stone over drain.
	Contingencies.
	Total Rs.
	Cuddapah slab removable drain covering 4' long for a 9" open drain.
2 c. ft. ...	Granite stone.
7 sq. ft. ...	Slab stone over drain.
	Contingencies.
	Total Rs. ...
	Cuddapah slab removable drain covering 4' long for a 12" open drain.
2 c. ft. ...	Granite stone.
8 sq. ft. ...	Slab stone over drain.
	Contingencies.
	Total Rs. ...
	Cuddapah slab removable drain covering 4' long for a 15" open drain.
2 c. ft. ...	Granite stone.
9 sq. ft. ...	Slab stone over drain.
	Contingencies.
	Total Rs. ...

Quantity.	Description of work.
	Cuddapah slab removable drain covering 4' long for a 18" open drain.
2 c. ft ...	Granite stone.
10 sq. ft. ...	Slab stone over drain.
	Contingencies.
	Total Rs. ...
	Cuddapah slab removable drain covering 4' long for a 21" open drain.
2 c. ft. ...	Granite stone.
11 sq. ft. ...	Slab stone over drain.
	Contingencies.
	Total Rs. ...
	Cuddapah slab removable drain covering 4' long for a 24" open drain.
2 c. ft. ...	Granite stone.
12 sq. ft. ..	Slab stone over drain.
	Contingencies.
	Total Rs. ...
	Removable iron frame covering, 2' long for a 6" open drain.
1 c. ft. ...	Granite stone.
7½ lb. ...	Iron work, round and flat bar iron.
... ...	Iron work, labour charge.
	Contingencies.
	Total for iron frame covering, 2' long.
	Total for iron frame covering, 4' long.
	Removable iron frame covering 2' long for a 9" open drain.
1 c. ft. ...	Granite stone.
10½ lb. ...	Iron work, round and flat bar iron.
... ...	Iron work, labour charge.
	Contingencies.
	Total for iron frame covering, 2' long.
	Total for iron frame covering, 4' long.
	Removable iron frame covering, 2' long, for a 12" open drain.
1 c. ft. ...	Granite stone.
13 lb. ...	Iron work, round and flat bar iron,
	Iron work, labour charge.
	Contingencies.
	Total for iron frame covering, 2' long.
	Total for iron frame covering, 4' long.
	Removable iron frame covering, 2' long, for a 15" open drain.
1 c. ft. ...	Granite stone.
16 lb. ...	Iron work, round and flat bar iron.
Do. ...	Do. labour charge.
	Contingencies.
	Total for iron frame covering, 2" long.
	Total for iron frame covering, 4' long.
	Removable iron frame covering, 2" long, for a 18" open drain.
1 c. ft. ...	Granite stone.
18 lb. ...	Iron work, round and flat bar iron.

Quantity.	Description of work.
18 lb. ...	Iron work, labour charge.
	Contingencies.
	Total for iron frame covering, 2' long.
	Total for iron frame covering, 4' long.
	Removable iron frame covering, 2' long, for a 21" open drain.
1 c. ft. ...	Granite stone.
$21\frac{1}{2}$ lb. ...	Iron work, round and flat iron bar.
Do. ...	Do. labour charge.
	Contingencies.
	Total for iron frame covering, 2' long.
	Total for iron frame covering, 4' long.
	Removable iron frame covering, 2' long, for a 24" open drain.
1 c. ft. ...	Granite stone.
$23\frac{1}{2}$ lb. ...	Iron work, round and flat bar iron.
	Do. labour charge.
	Contingencies.
	Total for iron frame covering, 2' long.
	Total for iron frame covering, 4' long.

Removable Drain Coverings Suitable For Wheeled Traffic: Plate 211.

In the above plate is illustrated the type design No. 104 issued with proceedings of the Madras Sanitary Board No. 113-S., dated 5-3-1909. The specification report which accompanied this design was as follows: 1. Two designs have been prepared: one shows a Cuddapah slab drain covering and the other cast iron chequered plate covering. 2. Cuddapah slab covering: On both sides of the top of drain at the place where it is proposed to permit a covering being laid, 3 to 5 cutstones $9'' \times 5\frac{1}{2}''$ to $6'' \times 4''$ long will be fixed. The object of the cutstone is to prevent damage to the masonry of the drain each time the covering is removed. On the top of the drain side of each cutstone will be cut a groove $6\frac{1}{2}'' \times 2\frac{1}{2}'' \times 3''$ in size to form bearings for the Cuddapah slab drain covering, the thickness of which will vary from $2\frac{1}{2}$ inches to 3 inches. 3. Chequered plate covering: Similar cutstones to that required for slab covering will be required in this case also. But the inside groove will be only $1\frac{1}{2}'' \times 3\frac{1}{2}''$ in size. The chequered plate will be as per design and dimensions shown in the plan. The plate will be made in 2 feet length for convenience in handling and for strength. 4. In both cases the top of the covering should be flush with the top of the cutstone and there should be a space of $\frac{1}{4}$ inch on either side of the covering between itself and the cutstone. Care should be taken to see that the covering lies firmly on the cutstone support which should be evenly dressed on the bearing surface. 5. There will be two holes each $3'' \times \frac{3}{4}''$ in each chequered plate of 2 feet length and one such hole in each 4 feet length of Cuddapah slab cover for letting in the lifting tool, which will be as per design in the plan and will be made in steel. 6. The following is the statement of approximate cost of the two kinds of coverings taking each covering as 4 feet in length.

Estimated cost for covering 4 feet long.

Drain, size in inches.		Cuddapah slab covering. Varies From RS. A. P.	Cuddapah slab covering. Varies To RS. A. P.	Iron covering Varies From RS. A. P.	Iron covering Varies To RS. A. P.
6	... ...	3 15 6	13 4 0	22 8 0	33 6 0
9	... ...	4 2 9	14 1 4	27 6 0	39 7 6
12	... ...	4 6 0	14 14 8	32 4 0	45 9 0
15	... ...	4 15 6	18 0 0	37 2 0	51 10 6
18	... ...	5 3 0	19 0 0	42 0 0	57 12 0
21	... ...	5 6 6	20 0 0	46 14 0	63 13 6
24	... ...	5 10 0	21 0 0	51 12 0	69 15 0

No provision is made in this for the lifting tool.

Abstract Of Quantities For Removable Drain Covering Suitable For Wheeled Traffic: Plate 211.

Quantity.	Description of work.
	Cuddapah slab removable drain covering, 4 feet long, for a 6" open drain suitable for wheeled traffic.
2·75 c. ft. ...	Granite stone at sides.
6 sq. ft. ...	Cuddapah slab.
	Total Rs. ...
	Cuddapah slab removable drain covering, 4 feet long, for a 9" open drain suitable for wheeled traffic.
2·75 c. ft. ...	Granite stone at sides.
7 sq. ft. ...	Cuddapah slab.
	Total Rs. ...
	Cuddapah slab removable drain covering, 4 feet long, for a 12" open drain suitable for wheeled traffic.
2·75 c. ft. ...	Granite stone at sides.
8 sq. ft. ...	Cuddapah slab.
	Total Rs. ...

Quantity.	Description of work.
	Cuddapah slab removable drain covering, 4 feet long, for a 15" open drain suitable for wheeled traffic.
3 c. ft. ...	Granite stone at sides.
9 sq. ft. ...	Cuddapah slab.
	Total Rs. ...
	Cuddapah slab removable drain covering, 4 feet long, for an 18" open drain suitable for wheeled traffic.
3 c. ft. ...	Granite stone at sides.
10 sq. ft. ...	Cuddapah slab.
	Total Rs. ...
	Cuddapah slab removable drain covering, 4 feet long, for a 21" open drain suitable for wheeled traffic.
3 c. ft. ...	Granite stone at sides.
11 sq. ft. ...	Cuddapah slab.
	Total Rs. ...
	Cuddapah slab removable drain covering, 4 feet long, for a 24" open drain suitable for wheeled traffic.
3 c. ft. ...	Granite stone at sides.
12 sq. ft. ...	Cuddapah slab.
	Total Rs. ...
	An Iron removable drain covering, 4 feet long, for a 6" open drain suitable for wheeled traffic.
3 c. ft. ...	Granite stone at sides.
156 lb. ...	Iron covering.
	Total Rs. ...
	An iron removable drain covering, 4 feet long, for a 9" open drain suitable for wheeled traffic.
3 c. ft. ...	Granite stone at sides.
195 lb. ...	Iron covering.
	Total Rs. ...
	An iron removable drain covering, 4 feet long, for a 12" open drain suitable for wheeled traffic.
3 c. ft. ...	Granite stone at sides.
234 lb. ...	Iron covering.
	Total Rs. ...
	An iron removable drain covering, 4 feet long, for a 15" open drain suitable for wheeled traffic.
3 c. ft. ...	Granite stone at sides.
273 lb. ...	Iron covering.
	Total Rs. ...
	An iron removable drain covering, 4 feet long, for an 18" open drain suitable for wheeled traffic.
3 c. ft. ...	Granite stone at sides.
312 lb. ...	Iron covering.
	Total Rs. ...
	An iron removable drain covering, 4 feet long, for a 21" open drain suitable for wheeled traffic.
3 c. ft. ...	Granite stone at sides.
351 lb. ...	Iron covering.
	Total Rs. ...
	An iron removable drain covering, 4 feet long, for a 24" open drain suitable for wheeled traffic.
3 c. ft. ...	Granite stone at sides.
390 lb. ...	Iron covering.
	Total Rs. ...

Closed Drainage.

In this system, by the use of closed sewers, all the objections stated against the open drainage system are absent. However, there is the difficulty of dealing with rainfall which falls on roofs and court yards during certain periods of the year, and the present condition of the houses and the habits of the people in India contribute an additional difficulty in the way of providing satisfactory house connections. Sectional pumping is provided usually dividing a town into a number of separate areas for sewerage purposes. In plate 196 is illustrated a specimen survey of lines of sewers in a plain country. On a perusal of this plate, it will be observed that the sewers are laid in streets with flush tanks at the head of each drain, manholes at each change of direction or gradient. On the straight run of sewers, manholes should be provided at intervals of not more than 300 feet, so that any part of the drainage system may be cleaned from one manhole to another with drain rods of the usual length of 150 feet. The designs for manholes are usually of the type shown in plates 199 and 200, where a manhole intervenes a change of gradient it is of the type shown in plate 201. The flush tanks at the heads of sewers are usually of the type shown in plates 197 and 198. A suitable design for a lamp-hole is illustrated in plate 202. Whenever sewage is discharged suddenly into a sewer, the air in the sewer is compressed and relieves itself either by escaping at outlets provided for the purpose or else by forcing its way through syphon traps. It is therefore necessary that the air in sewers should be kept fresh by a well arranged system of ventilation so that any air escaping from them may be as innocuous as possible. The usual methods adopted for ventilation of sewers consist of ordinary road ventilators or else an arrangement of low level fresh-air inlets and high

level outlets, or a combination of the two methods. For Indian conditions, the arrangement of low level fresh-air inlets and high level outlets has been found satisfactory and should be adopted. There should also be a ventilating shaft at flush tanks at heads of sewers as shown in plates 197 and 198. The sullage of houses is connected to the sewers by means of house connections. As already stated, considering the existing conditions of the houses and the habits of the people, a pattern of house connection satisfying not only the sanitary requirements expected of them but also the imaginary grievances and objections of people cannot be designed. In plate 203 are shewn patterns of house connections, air-inlets, ventilating arrangements for cess-pits, junction manholes, etc., as designed by Mr. Hutton.

Sizes And Gradients Of Sewers.

The essential principles on which the sizes of sewers are determined are as follow: 1. That 4 inch and 6 inch sewers should have a velocity usually of 3 feet to 3½ feet per second when flowing full or half full and an absolute minimum velocity of 2½ feet per second flowing full or half full. 2. That 9 inch sewers and sewers above 9 inches in diameter should have a velocity when flowing full or half full of 2½ to 3 feet per second usually and 2 feet per second as an absolute minimum. 3. That the sizes of sewers should be so fixed that when they are flowing half full, they are capable of carrying the maximum discharge of sewage from the prospective population for which the sewerage scheme is designed. 4. That the length of each 6 inch sewer should be limited to 300 feet and beyond this distance up to the point where the 6 inch sewer will end according to calculations there should be a 9 inch sewer, laid however with the gradient as if it was a 6 inch sewer. Similarly, 9 inch sewers should be increased to 12 inches and 12 inches to 15 inches and so on. Foul drains or sewers are said to be self-cleansing when the flow of sewage which ordinarily comes down them is sufficient to keep them free from deposit. To secure this result in practice, the sewers should be laid with such even gradients as would give the velocities stated above as absolute minimum requirements. The following table gives the gradients required to ensure different velocities of flow when flowing full or half full calculated by Kutter's formula given on page 186. The amount of discharge of sewers when flowing full is also given in the table.

Size of sewer in inches.	Fall 1/— over.	Velocity in feet per second.	Discharge in gallons per minute.	Fall 1/— over.	Velocity in feet per second.	Discharge in gallons per minute.
4	82	2	65	52	2 5	82
6	160	2	146	100	2·5	185
9	300	2	330	190	2·5	415
12	465	2	537	295	2·5	739
15	640	2	922	415	2·5	1150
18	840	2	1324	540	2·5	1660
20	980	2	1633	630	2·5	2047
21	1050	2	1801	680	2·5	2250
24	1250	2	2371	820	2·5	2943
27	1500	2	2974	970	2·5	3722
30	1750	2	3656	1100	2·5	4646
33	1950	2	4474	1300	2·5	5522
36	2200	2	5323	1490	2·5	6604
39	2500	2	6188	1600	2·5	7795
42	2750	2	7192	1800	2·5	8959
45	3000	2	8281	1950	2·5	10355
48	3300	2	9371	2150	2·5	11714
4	44	2·75	89	37	3	97
6	84	2·75	202	71	3	220
9	160	2·75	453	135	3	494
12	245	2·75	812	210	3	877
15	345	2·75	1263	290	3	1379
18	450	2·75	1821	380	3	1893
20	530	2·75	2235	440	3	2457
21	560	2·75	2484	475	3	2700
24	680	2·75	3238	570	3	3542
27	810	2·75	4080	680	3	4459
30	930	2·75	5061	790	3	5499
33	1050	2·75	6158	900	3	6660
36	1200	2·75	7278	1000	3	7989
39	1350	2·75	8506	1150	3	9232
42	1500	2·75	9839	1250	3	10801
45	1650	2·75	11288	1350	3	12504
48	1750	2·75	13025	1500	3	14092
4	27	3·5	114	21	4	129
6	52	3·5	257	40	4	293
9	98	3 5	580	76	4	659
12	150	3·5	1040	120	4	1163
15	215	3 5	1604	165	4	1833
18	280	3·5	2315	215	4	2645
20	325	3·5	2864	250	4	3269
21	350	3·5	3152	270	4	3593
24	425	3·5	4110	330	4	4668
27	500	3·5	5211	385	4	5949
30	580	3·5	6435	445	4	7356
33	660	3·5	7798	510	4	8888
36	750	3·5	9247	570	4	10625
39	830	3·5	10898	640	4	12433
42	920	3·5	12628	710	4	14399
45	1000	3·5	14571	780	4	16529
48	1100	3·5	16511	850	4	18817
4	16	4·5	148	13	5	164
6	31	4·5	333	26	5	364
9	60	4·5	742	48	5	830
12	93	4·5	1322	75	5	1472
15	130	4·5	2065	105	5	2300
18	170	4·5	2976	140	5	3281
20	195	4·5	3705	160	5	4092
21	210	4·5	4077	175	5	4470
24	255	4·5	5320	210	5	5866
27	305	4·5	6690	245	5	7473
30	355	4·5	8248	285	5	9210
33	405	4·5	9985	325	5	11157

Size of sewer in inches.	Fall 1/— over.	Velocity in feet per second.	Discharge in gallons per minute.	Fall 1/— over.	Velocity in feet per second.	Discharge in gallons per minute.
36	455	4·5	11905	370	5	13216
39	510	4·5	13946	410	5	15567
42	560	4·5	16237	455	5	18031
45	620	4·5	18562	500	5	20693
48	670	4·5	21224	550	5	23448
4	11	5·5	178	9	6	197
6	21	5·5	405	18	6	437
9	40	5·5	909	34	6	986
12	62	5 5	1620	52	6	1769
15	87	5·5	2527	73	6	2759
18	115	5·5	3621	96	6	3964
20	130	5·5	4537	110	6	4942
21	140	5·5	4998	120	6	5402
24	170	5·5	6522	145	6	7064
27	205	5·5	8173	170	6	8959
30	235	5·5	10153	200	6	11011
33	270	5·5	12250	230	6	13276
36	305	5·5	14564	255	6	15938
39	340	5·5	17106	285	6	18697
42	375	5·5	19876	315	6	21696
45	415	5·5	22729	350	6	24762
48	450	5·5	25942	380	6	28248

Flushing.

Even if the sewers are laid with self-cleansing velocities, as stated in a previous lecture, it is necessary that provision should be made for flushing as the sewage flow alone cannot be regulated to effect the necessary flushing to sweep away all deposits in the sewers and prevent the generation of sewer gases. Plates 197 and 198 illustrate the designs proposed for such flushing tanks. For escape of sewer gas these designs are provided with ventilating shafts and to enable the automatic Field syphons to operate, 2″ wrought iron tube air-inlets are also provided. For sewers, the sizes of the tanks are shewn in the following table:

Sizes of sewers in inches.	Capacity of flush tank in gallons.
4 or 6	99
9	227
12	370
15	640
18	1010
21	1670

Advantage should be taken of utilising the sewage from branch sewers, where possible, to flush sewers running on a lower level in order to economise the use of drinking water supply for flushing purposes. Another suitable location for flushing tanks is near public fountains so as to utilise the spill water in the flushing tanks. In the cases of sewers of small lengths up to 100 feet, lamp holes should be provided at the head of each sewer for the purpose of flushing from buckets or barrels.

Ventilation.

Ventilation to every part of the sewer is proposed to be effected by providing manholes with air inlets for admission of fresh air and with ventilating shafts for escape of sewer gas, on the following principles: There should be an air inlet manhole at every 600 ft. apart commencing from the junction of the sewer at its deep end; and a ventilating shaft manhole at every 600 feet commencing from the head of the sewer, so that at every 300 feet on the line of the sewer there will be either an air-inlet or a ventilating shaft manhole. Manholes with cast iron surface boxes should be provided in all cases where they may require to be often opened for cleansing or inspection purposes and where no similar manhole is available within 300 feet.

Junctions Of Sewers With Open Drains.

Owing to the small widths of lanes, the larger lanes being not more than 6 feet wide, and when the inclination of the lane permits of an open surface drain and the cost of house connections and platforms for such small lanes would be prohibitive, the drainage of such lanes should be provided for by open surface drains terminating in a junction pit and connected to the main sewers by a suitable trap and ventilating shaft.

House Connections.

The patterns of these are shewn in plate 203 and call for no further remarks. As the sewer ventilation is proposed to be effected by provision of air-inlets and ventilating shafts at manholes it will be noticed that no provision for ventilating the house connections has been made nor is it required. From an inspection of the house connection it will be noticed that if the water seal of the trap is broken by pressure of sewer gas from the main sewer such gas will escape naturally upwards from the top opening of the house connection and will not pass into the house.

General Principles And Data.

Having selected the system on which the drainage of a town is to be carried out, the plans should be carefully prepared so as to ensure accuracy and uniformity throughout. The location of outfall works where the sewage is to be finally delivered should be carefully considered and decided on, especially where pumping of sewage at disposal works has to be resorted to. In schemes where final pumping of sewage is unavoidable, the works should be designed with minimum gradients to minimise the lift and the consequent cost. The depths of the

sewers below ground must be so regulated as to enable them to drain the basements of houses and also to prevent damage to sewers by traffic. The minimum depth of a sewer at commencement is usually $3\frac{1}{2}$ feet. The maximum depth of stoneware pipe sewers is regulated by the subsoil water level of the town. Sewers to be laid at depths exceeding 15 to 16 feet are cast iron. The sewers should as a rule, be laid in straight lines and with even gradients between manholes. The house connection pipe drain should never join the street sewer at right angles, but should always join at a slant along the direction of the flow of sewage. This arrangement is essential to avoid disturbance to the proper flow of sewage along its intended course. For the same reason, the floors of manholes should be curved as shewn in the designs illustrated in plates 199 and 200. Quantity of sewage: The size of sewer depends on the amount of sewage to be dealt with. A careful account should be taken of the quantity of sewage of the population in the area to be drained and also of the population from the neighbouring areas which may be included in the future. The usual practice is to take the water supply as a guide and to provide for a constant daily supply of sewage of equal amount. As in the case of water supply, an allowance must be made for the prospective increase of population. Admission of rainfall: The quantity to be provided for under this head is yet an unsettled question. The usual practice is to provide an allowance of rainfall at the rate of $\frac{1}{2}$ inch per day per house over an average area of 1,000 square feet. If the sizes of sewers are fixed on the principles described before it will be found that the sewers are sufficiently large to take six times the dry weather flow of the prospective population with a reasonable allowance for ventilation while conveying sewage at same time with minimum standard velocities. At suitable points, and at pumping stations, provision should be made for overflow arrangements to surplus the excess water due to rainfall into nearest water courses or channels.

DRAINAGE: MATERIALS AND THEIR USE: THE USE OF DRAINAGE PIPES, GLAZED AND UNGLAZED BRICK DRAINS, SYPHON TRAPS, CESSPOOLS, ETC.

Materials.

It will be admitted that in any work, the best materials are always the cheapest in the long run. Special care to conform to this rule in the case of drainage materials is necessary, for in ordinary building work the materials are not subjected to deteriorating influences as in the case of drainage works and any damage in the former case becomes apparent while in the latter it is not detected till it has assumed serious proportions entailing danger to health. The materials used in drainage work should not only be durable but also be those least liable to be affected by damp, by the chemical qualities of sewage, and by sewage gases. Stoneware drain pipes should be homogeneous in texture, impermeable to water, uniform in thickness, cylindrical throughout, straight, and strong enough to resist bursting by moderate pressure. The impermeability of the pipe itself should further be assisted invariably by its being glazed. The bricks used for drainage works should be specially well burnt and hard. The cement should be the best English Portland cement conforming to standard specifications.

Syphon Traps.

In fig. 7, plate 221 is illustrated a trap which is a term applied to the dip or bend in a sewer. The object of a trap is to break the direct line of connection between the air contained by two portions thereof. The portion A B in the illustration is termed the effective seal of the trap and the water retained is said to seal the trap. The standard depth of seal generally accepted is $2\frac{1}{2}$ inches and $1\frac{1}{2}$ inches is considered the minimum seal admissible. Traps may be sub-divided into 'S' traps, 'P' traps, disconnecting traps, grease traps, syphon traps, intercepting traps, etc.

Cesspools.

In localities, where there are no gardens attached to each house, necessitating the removal of house sullage by collecting it in fronts of houses, cesspools, otherwise called catch pits or sink-pits, are provided. If these pits are pervious the subsoil is fouled near houses to an abominable extent. In impervious cesspools, they have to be emptied at frequent intervals into water tight carts to be conveyed to some locality to be disposed of in a suitable manner, minimising the objectionable character of the raw sewage. In practice, difficulties occur in connection with the regular removal of the contents of cesspools. The provision of cesspools as a method of sullage removal from houses has nothing to be said in its favour; and the provision of sink-pits below ground level fouling the subsoil and surroundings, evolving an abominable smell, possesses many disadvantages apparent to all and too numerous to mention. An arrangement for ventilating a cesspit and for a disconnecting syphon between house drain and drop outlet is illustrated in plate 203.

DRAINAGE: PROPER CONSTRUCTION OF DRAINS: THE VARIOUS METHODS OF PIPE JOINTING IN CLOSED DRAINAGE AND SUBSOIL DRAINAGE: TESTING AND MAINTENANCE OF DRAINS: THE METHODS OF FLUSHING AND CLEANING DRAINS AND OF DRAIN TESTING: THE VARIATION IN SUBSOIL WATER LEVEL AND ITS EFFECT ON HEALTH: THE METHODS OF EXCLUDING SUBSOIL WATER FROM AREAS AND SPACES BELOW GROUND LEVEL: SIMPLE PLANT FOR DOMESTIC SEWAGE DISPOSAL.

Pipe Jointing.

The joints of pipes in closed sewerage schemes should be made with special care as leakage occurs mostly at joints. The joints of stoneware pipes should be done with neat Portland cement or of 1 part cement to 1 of sharp sand. Sewer pipes should always be laid with the socket at the higher end. It is therefore necessary to commence at the lower end and work upwards. The drains should be laid accurately with boning rods from point to point after lining and levelling the sewer line. Any carelessness in the preliminary operation of lining and levelling will result in serious consequences. The sites of manholes with levels of the inverts of pipes entering and leaving it should be carefully marked. Pipe sewers, unless they are well jointed with strong and water-tight joints, will be of little value. Care should therefore be taken that the pipes are truly concentric, that no cement is forced up inside the joint, that the socket is properly filled with cement, especially on the underside. Several kinds of sockets and spigots have been invented but none of them are of a character not to need best workmanship and supervision in laying and jointing. Stoneware pipes should not be used in situations in which the velocity of flow in the sewer is more than 4 feet per second. In water logged ground and in all situations where there is a likelihood of a stoneware drain giving way, owing to pressure, settlement of the ground, stoneware pipes should not be used. In such cases, cast iron drainage pipes should invariably be used. The cast iron pipes used in drainage works should be plain, socket and spigot pipes which are jointed with lead as described under water supply. Cast iron drainage pipes possess many advantages over stoneware pipes, the only drawback being the extra cost involved. However, if the security obtained by the more durable cast iron pipes is considered, there is no doubt that the most economical material for drainage pipes will be cast iron.

Subsoil Drainage.

In a previous chapter I have discussed the necessity of a healthy dwelling site having its subsoil water as low as possible and at a constant level. Low-lying, clay and water logged soils account for the general health of the people living in such areas being very low. If the level of subsoil water is lowered, then the climate of such areas is drier and more healthy. Channels, streams, water courses and rivers are effective for the natural drainage of land in ordinary soils and circumstances. In certain situations, to improve the sanitation of the place, pipe draining is adopted to keep the level of the subsoil water at some distance below the surface of the ground and at a constant level, if possible, or fluctuating as little as possible. An arrangement of subsoil drainage is shown in fig. 1, plate 220; and in fig. 2 is shown the section through upper end of drain and in fig. 3 the section through lower end of drain. The filling above the pipe usually consists of large gravel or broken stone. The subsoil drains are usually laid with the available fall of the land or about 1 in 150. The distances apart of drain pipes depend on their depth, on the slope of the ground, and on the character of the soil. They are generally 4 feet deep spaced 20 to 27 feet apart in stiff clay soils, 30 feet apart in heavy soils and 40 feet apart in light soils. When the subsoil water fluctuates much, large sized deep subsoil drains would be more effectual than a number of small drains. The pipes in subsoil drainage are usually open jointed or wedge jointed. In the case of foul drains, the joints of sewers should be water-tight, while in the case of subsoil drains, they are left in position by means of stone wedges inserted into the sockets of pipes. For small areas, trenches or ditches dug all round the area with an outfall into the nearest channel will draw away the moisture

from beneath the footings and leave the foundation soil undisturbed.

Testing Drains.

All sewers should be tested from the lowest point to the highest, at the time the drainage works are being carried out, with the object of ensuring and proving that the works have been well done, that the sewers and manholes are water-tight, that the soil pipes, ventilating pipes and connections are water-tight and air-tight. The two most reliable tests made use of for proving the soundness of the drains are the hydraulic or the 'water' test and the pneumatic or 'air' test. The underground sewers should be tested for soundness by the water test. The method of testing with water is by plugging the lower end of a sewer by one of the numerous plugs now made for the purpose and by filling the sewer with water. At the upper end, a bent pipe set vertically or a special plug having a union on it is inserted to which is attached an India rubber tube carried to the gauging can at ground level. Branch drains should invariably be laid and tested simultaneously with the main sewers. The object of the water test is to test the joints of pipes and not the quality of the pipes themselves. The testing of the quality of the pipes used in drainage works should be done, before the pipes are sent to the work spot. Leakiness of joints, absorption by pipes and joints and sweating of pipes and joints are the factors which cause any subsidence of water after the sewer has been filled with water. A uniform rate of subsidence indicates leakiness of joints which will be visible to the eye or may be ascertained by feeling under each joint. A diminishing rate of subsidence, the rate getting less and less till no further subsidence takes place indicates absorption by pipes and joints. Slight but continuous subsidence of the water indicates sweating of pipes and joints. In applying the pneumatic test, all openings on the drainage system or of a section thereof such as gullies, closets, vent pipes, etc., are carefully sealed and air pumped into the drains. The pressure attained is indicated on a gauge attached to a plug closing one of the openings in the drain. The gauge being carefully watched after the desired pressure has been obtained, the soundness or leaking conditions of the drains under test will be indicated by the constancy or the diminution in pressure respectively. The 'smoke' test and the 'olfactory' test are the other tests made use of in drainage works. Smoke test consists in pumping into the drain through a manhole or other opening in the drains, the smoke generated by a smoke machine so that the defective points may be apparent by the escape of smoke. Olfactory test consists in the sewers being charged with some pungent or otherwise distinctive smell so that the escape of smell through defective places may be detected. Both the smoke and the smell test are unreliable for proving soundness.

Filter Trench For A House: Plate 206.

In the above plate is illustrated the type design No. 103 issued with proceedings of the Madras Sanitary Board No. 251-S., dated 15-8-07. The specification report which accompanied this design was as follows: Estimated cost Rs. 6. The sullage water from the house to be provided with a filter trench should be conveyed by an oval-shaped cement plastered drain to the most open and extensive plot of ground available in the compound of the house. The most suitable location of a filter trench is in the garden of the house, provided there is not a drinking water well within an appreciable distance into which there is a chance of the sullage water ultimately finding its way from the filter trench. At the end of the house drain, a catch pit 12″ × 12″ × 6″ intended to arrest stones, straw and debris brought down by the house drain is shown on the plan. This catch pit is intended to be cleaned out periodically and the solid contents deposited in the dustbin or buried in the garden according to local arrangements. The sullage water from the house after passing across the catch pit is intended to flow through a grating made of iron rods, ½ an inch apart in which all leaves and other floating debris will be caught and removed at the same time as the stones, etc., from the catch pit. After passing through the grating the sullage water will flow over a bed of sand, 6′ × 2′ by 12″ deep. Here it will slowly filter through the sand and the underlying 2 feet bed of broken stone and so be diffused through the subsoil after its objectionable character has been removed by the filter bed. In situations which permit, it is a good plan to provide a 3″ drain pipe from the bottom of the stone layer, leading into the nearest ditch. The object of the drain pipe is to ensure that the bottom of the stone filling is kept dry as it is fatal to the successful working of a filter trench if it becomes waterlogged by the rising of the subsoil water. In the plan the highest subsoil water level is shown some distance below the bottom of the filter trench and in such situations the trench should fulfil its purpose. It will be noticed that there is no protecting bund around the filter trench to exclude drainage caused by heavy rainfall, It is presumed that the filter trench will be placed where it is not liable to be swamped by a sudden and heavy shower. When the surface of the sand layer becomes clogged, as it will in time, it can be scraped, one inch in depth of sand being removed at each scraping. After three such scrapings, 3 inches of fresh sand should be added so as to restore the bed to its original condition. Notes on location and working of filter trenches: (1) A house,

unconnected with a general sewerage system, where the subsoil water level is not too near the surface, say 6 feet, and the soil and the ground level of the backyard are suitable for drainage of the effluent, may be provided with a filter trench. (2) The size of a filter trench should not vary; if from the amount of impurity the filter gets choked, it can be cleaned the more frequently. (3) Cleansing filter trench by the Municipal scavenger: The drain, catch pit and grating daily. Surface of filter, once or twice a week. The whole filter once or twice a year as required.

Abstract Of Quantities For A Filter Trench For A House: Plate 206.

Quantity.		Description of work.
52 c. ft.	...	Earthwork, excavation.
2 „	...	Concrete, broken stone in surkhi mortar.
10 „	...	Brickwork in surkhi mortar.
24 sq. ft.	...	Plastering with cement, ½" thick.
24 c. ft.	...	Filling in with broken stone.
12 „	...	„ clean sand.
		Grating of ⅜" bars, ½" apart, fixed to flat iron including fixing complete.
		Petty charges.
		Total Rs.

DRAINAGE: METHODS OF SEWAGE PURIFICATION: THE ACTION OF THE SEPTIC TANKS, BACTERIAL AND OTHER FILTERS AND OF LAND, ETC.: THE RELATION OF THE SEPTIC TANK TO THE OLD CESSPOOL: THE FORMATION OF SMALL COLLECTING TANKS AND AREAS FOR SEWAGE FILTRATION: THE PROPER CROPS TO GROW UNDER SEWAGE IRRIGATION: THE SUBSOIL DRAINAGE OF SEWAGE FARMS, WHEN NECESSARY AND WHEN NOT: THE MAXIMUM AREA WHICH CAN BE IRRIGATED BY ANY QUANTITY OF SEWAGE: THE MAXIMUM AMOUNT OF SEWAGE WHICH CAN BE PUT IN AN AREA TO ENSURE A MAXIMUM RETURN IN RELATION TO TEMPERATURE AND CLIMATE.

Disposal Of Sewage.

Outfall is the place at which the sewage of a town is finally discharged by sewers or drains. Works that are carried out at outfall are called 'outfall works' or 'disposal works.' The disposal works may be discussed under land treatment, chemical treatment with tank precipitation and artificial filtration, and bacterial treatment. In addition to these, sewage may be discharged into running streams, tidal rivers and into the sea. Crude sewage is the sewage as produced and conveyed by sewers and drains to disposal works. When the crude sewage is treated at outfall works either on land or through bacterial filters or by precipitation and artificial filtration chemically, the effluent after such treatment is called 'treated sewage' or 'filtered sewage effluent.' The requirements of the London Local Government Board in the matter of the disposal of sewage, may be thus summarised: 1. That only 6 times the dry weather flow must be conveyed to the sewage works for treatment, and that anything above that quantity must pass through storm overflows, as a dilution of 5 of water to 1 of sewage is considered to be sufficient to render the sewage practically harmless to pass off into a river or stream without any further treatment. 2. That sewage when diluted with water in the proportion of 2 of water to 1 of sewage, should be treated as 'strong' or 'crude sewage.' 3. That sewage mixed with water between 3 times to 6 times the dry weather flow need not be fully treated as crude sewage, but should however receive special treatment.

Methods Of Sewage Purification.

Before proceeding to consider the various means adopted for purifying sewage, it will be well to refer to the question of the standard of purity of sewage desired. Crude sewage contains about 100 grains of solid matter per gallon, of which one-third is in suspension and two-thirds in solution. The substances, present in sewage, which is water that has been fouled with various matters, chiefly human and animal excreta and waste water from houses, markets and stables, may be classed under 1. Organic matters in suspension in the water. 2. Mineral matters in suspension in the water. 3. Organic matters in solution in the water. 4. Mineral matters in solution in the water. It is of course impossible to state a fixed standard of purity universally applicable. It may, however, be necessary to know a safe standard for average conditions as a guide to check the results in particular cases. The standard fixed by Royal Commission on sewage disposal is "that an effluent can best be judged by ascertaining, first, the amount of suspended solids which it contains, and second, the rate at which the effluent, after the removal of the suspended solids, takes up oxygen from water. In applying this test, it is important that the suspended solids should be removed and estimated separately. For the guidance of local authorities we may provisionally state that an effluent would generally be satisfactory if it complied with the following conditions: 1. That it should not contain more than 3 parts per 1,00,000 of suspended matter. 2. That, after being filtered through filter paper it should not absorb more than: (a) ·5 part by

weight per 1,00,000 of dissolved atmospheric oxygen in 24 hours, (*b*) 1·0 part by weight per 1,00,000 of dissolved or atmospheric oxygen in 48 hours, (*c*) 1·5 part by weight per 1,00,000 of dissolved or atmospheric oxygen in 5 days." Analytical results are stated usually in parts per 1,00,000. Sometimes they are recorded in grains per gallon. In this case, to convert to parts per 1,00,000 the conversion equivalents are: one lb. avoirdupois equals 7,000 grains and one gallon of water equals 70,000 grains so that 7 grains per gallon equal 10 parts per 1,00,000. Thus, to convert grains per gallon to parts per 1,00,000, divide by 7 and multiply by 10, or conversely to convert parts per 1,00,000 into grains per gallon, multiply by 7 and divide by 10. Dr. Barwise suggests the following standard as generally suitable: "Total suspended matter less than 3·0 parts per 1,00,000; Oxygen absorbed at 80 degrees Fahrenheit in 4 hours less than 1·5 parts in 1,00,000; Albumenoid ammonia less than ·15 parts per 1,00,000; Nitrogen as Nitrates to be at least ·25 parts per 1,00,000." The principal methods in use for the purification of sewage may be broadly classified as 1. process for preliminary clarification by means of screening, sedimentation, precipitation either with or without chemicals and by liquefying in the septic tank; and 2. methods for the final oxidation of the impurities contained in the clarified liquid by land treatment, either in the form of broad irrigation or land filtration and by contact beds or percolating filters. Before explaining these methods it would be as well to explain the principles of the biological process. It has been ascertained by experiments that sewage can be purified by liquefying and by oxidising organisms. Liquefying organisms exist without air and are generally classed as 'anaerobics' while oxidising organisms need air as an essential requirement and these are classed as 'aerobics.' From this explanation, it will be seen that, for micro-organisms to act on sewage, it will be necessary that the sewage must be brought under conditions required for the two classes of organisms such that 'anaerobics" have first free play followed by 'aerobics.' The objects aimed at in any treatment of sewage are: "1. Freedom from sewage odour. 2. Freedom from turbidity and suspended organic matters. 3. A condition of stability so that further putrefactive changes are not likely to arise, this being due to the reduction of the putrefiable organic matters in the raw sewage to an amount in the effluent that is proof against putrefactive processes owing to its dilution with water. The amount of putrefiable organic matter in an effluent is most readily determined by the oxygen absorbed by a known volume of the liquid in a certain time and at a certain temperature, and this can be contrasted with the oxygen absorption for the crude sewage, the result being usually expressed as a percentage reduction. In a similar way, a comparison of the albumenoid or organic ammonia in an effluent and sewage will show the reduction which has been effected in the organic matters originally present; whilst the amount of nitrates present in the effluent indicates the oxidation to which the sewage has been submitted in the aerobic beds, and is also an index of the 'stability' or freedom from liability to further putrefaction which the effluent has attained." The methods adopted to give practical application to the process of purification outlined above will now be described.

Sullage Disposal Works For A Detached House: Plate 205.

In the above plate is illustrated the design drawn up by Mr. Hutton, Sanitary Engineer to the Government of Madras, for certain Local Bodies in the Presidency of Madras. The sullage of a detached house is assembled at one point from which 4 inch stoneware pipes are laid to convey the sullage for disposal in a filter well. The filter well is 4 feet in diameter and is built with a depth of 6 feet. The bottom 4 feet will be filled with broken vitrified bricks. There will be a distributive channel on the surface of the filling. At one end of the filter well there will be a ventilating shaft as shewn in the design.

Septic Tank.

As far as Indian conditions are concerned, the usual procedure is to provide septic tanks in the case of such schemes which bring to the outfall the night-soil of the population for which the scheme is intended. In schemes in which the night-soil of the population is disposed of on the conservancy system, a septic tank is not considered an essential requirement and the crude sewage is treated directly on the sewage farm. A septic tank is really a huge cesspool. When sewage is stored in a tank or cesspool, the anaerobic process at once commences and if the septic tank or cesspool is left undisturbed, nature provides a thick coat of scum which excludes light and air thus developing the anaerobic form of life. The organic matter held in suspension in the sewage naturally sinks to the bottom of the cesspool, and it is at the bottom, the bacteria collect mostly. As sewage necessarily should enter the tank, there must necessarily be some movement of sewage in the tank. This, of course, cannot be helped. The tank, however, must be made large enough so that the sewage entering the tank is diffused and its velocity so reduced causing the solids held in suspension in the sewage to be disposed at the bottom mildly and

the organisms are disturbed as little as possible. The septic tank need not be necessarily roofed as the scum produced on the top is so thick and stout to prevent air and light entering in the tank for the growth of the anaerobic bacteria. The maximum capacity of a septic tank should hold a 24 hours' supply of crude sewage. As in practice, a tank to hold this quantity of sewage is likely to be very large, many engineers are satisfied with a tank of 12 or even a minimum of 6 hours' supply of crude sewage. As a rule, the sewage is passed through grit or sludge or detritus or screening chambers before the sewage is passed on to the septic tank. A design of a detritus and sedimentation tank is shown in fig. 5 and a setting tank in fig. 4 in plate 221. Design for septic tanks are shown in plates 208, 215, and 216 ; a catch-pit and sludge well are shown in plates 213 and 219. In some cases, absolute rest tanks are provided to effect a settlement and to dispose of the precipitated sludge through a sludge pen stock. A section of such a tank is shown in fig. 6, plate 221. With quiescent sedimentation the tanks are usually made large enough for 2 or 3 hours settlement, the top sewage being drawn off by floating arms as shown in the figure. The preliminary treatment in such cases is necessary as silt retards the growth and action of bacteria in septic tanks. The sole object for which a septic tank is introduced is the growth of anaerobic bacteria and the septic tanks need not be necessarily roofed if the sewage enters so that the velocity is reduced. The depth, as some say, of the septic tank is 4 feet and others say, 8 feet. Therefore the minimum depth recommended for a septic tank is 4 feet and the maximum 8 feet. Having known the depth, the area of the tank may be found out. The maximum depth at which the sewage should enter the tank is stated as 15 inches below the full supply level of the tank, but the present day practice is to make the top of the inlet and outlet pipes to be at the same level as the full supply level of the tank.

Bacterial And Other Filters.

As already stated, the second stage of sewage purification is carried out upon sewage filters or upon land. Sewage filters, as now constructed, are divided into two main classes, *viz.*, 'contact beds' and 'percolating or continuous filters.' "Contact beds consist of tanks filled with material such as broken stone, clinker, etc., and used by filling them up with tank effluent until the filtering medium is just charged with sewage, allowing it to stand for a given period, draining off, and standing empty. The usual cycle of these operations is as follows: Filling, one hour. Standing, two hours. Draining, one hour. Aerating four hours. Total8 hours. With this cycle, three fillings per day are possible, and as the liquid capacity of a bed is 33 per cent. of its gross capacity, it follows that a bed is capable of treating each day a quantity of tank effluent equal to its gross capacity, that is when containing no filtering medium. The operations of filling and emptying may be done by hand valves or by automatic valves worked by floats. The depth of contact beds should not exceed 4 feet. The second class of bacteria beds consists of masses of hard rough material, such as broken stone or slag of gauges varying from 3 inches to ¼ inch over which the tank effluent is distributed in the form of spray, and through which it percolates. The bed may or may not be enclosed by means of side walls, but it must have a good substantial floor, efficient means of drainage and a proper system of distribution if good results are to be obtained. The depth of the beds varies from 4 feet to 10 feet depending upon the fall available and the size of the filtering medium. The quantity of tank effluent, which can be applied per square yard of surface of the bed, depends upon the strength of the sewage and size of the material employed for filtering and varies from 100 gallons per square yard per day to as much as 400 gallons, but this quantity cannot be maintained for long. A good average quantity is 150 gallons per square yard per day ; this will allow the bed to take the hourly fluctuations in the rate of flow of sewage and for short periods it will take storm water up to 3 times the figure named. The sprinkling process can be effected by a variety of arrangements, most of which have revolving arms operated in different ways, but there are also fixed jets and reciprocating travellers for rectangular beds. The relative merits of contact beds and percolating beds are as follow : 1. Where there is not much fall available, single contact beds can be constructed with about 3 feet 6 inches of fall ; double contact beds require 7 feet. A continuous filter may be constructed with a fall of about 5 feet 3 inches, but if a coarse filtering material is to be used, this must be increased by 2 feet or possibly more. 2. The tanks used for contact beds must be water-tight and therefore the facilities of the site for making water-tight beds must be taken into consideration. 3. The weight of the material used in a continuous filter is greater than that of a contact bed and therefore the stability of the ground must be taken into consideration. 4. Double contact beds must be provided if an equivalent degree of purification is required to that produced by a continuous filter. 5. Contact beds must be worked by automatic gear if three fillings per day are required, but may be operated by hand if two fillings are sufficient. 6. Generally speaking, the gear for operating continuous filters is less liable to get out of order than that for contact

beds. 7. Where the facilities for reducing suspended solids are limited, contact beds will sludge up and deteriorate much more quickly than continuous beds. 8. Percolating beds are more adaptable to fluctuating rates of flow than contact beds. 9. The first cost of percolating filters is less than that of contact beds, for equal quantities of sewage. 10. Generally speaking, continuous filters give better results than contact beds." (Kemp's 1910 Year book.)

Disposal Works For A Medical Institution.

A scheme was drawn up by Mr. Hutton for the drainage of the Lunatic Asylum, Madras, and the plans which he exhibited at the 'All India Sanitary Conference' at Bombay are shewn in plates 212 to 219 and his description of the scheme was as follows: "Shortly after passing through the east wall, the sewage will enter a catchpit and the excess storm water will pass over a weir into a storm overflow drain which will convey it to the Ottary nullah. After the sewage passes through the catchpit, where floating debris and mineral matter will be caught, it will pass through two small septic tanks each of 13,333 gallons capacity. From the septic tanks the sewage will pass through two Stoddart filters. The effluent from the filters will alternatively pass either to the Ottary nullah direct or to a suction well whence it will be lifted by a centrifugal pump, to be driven by an oil-engine, on to a sewage farm. This sewage farm will have an area of $5\frac{1}{2}$ acres and will be under-drained by drains placed 90 feet apart. The soil of the farm is clay loam and is not suitable for treatment of raw sewage. The farm will be utilised as a night-soil trenching ground or alternatively the night-soil of the Asylum will be dumped into the septic tanks by a slight re-arrangement of the inlet drains and the use of a hose. The quantity of water used per mensem at the Asylum as stated by the Superintendent is as follows: Red Hills pipe water, 4,50,000 gallons. Well and picottah water, 4,50,000 gallons, Total, 9,00,000 gallons. To this should be added an allowance for fluctuation in quantity and increased population, say, 3,00,000 gallons. Total quantity that may require to be treated, 12,00,000, say, 40,000 gallons daily. The general arrangement of the proposals is shown in plate 212. The following is a detailed description of the works. Catchpit: The main outlet drain of the Asylum is a 30-inch open drain. After passing through the east wall this drain is bifurcated to the north as a 12-inch sewage or sullage drain and to the south as a 30-inch storm overflow drain. The 12-inch sullage drain enters a catchpit of two compartments which act as a silt trap, the floor being depressed 9 inches below level of bottom of drain. The second compartment also contains an iron grating made of $\frac{1}{2}$ inch rods with $\frac{1}{2}$ inch spaces. At the end of this compartment there will be a regulating wooden shutter. The silt from this catchpit will be periodically removed and trenched and the grating will be periodically scraped. The design of the catchpit is shown on plate 213. Septic tanks: The effluent from the 12-inch open drain, after passing the catchpit or silt chamber, will flow through two branch open drains and later to septic tanks. The plan of the tanks is shown in plates 215 and 216. The capacity of each tank is 13,333 gallons so that the combined capacity is rather more than 12 hours' flow. The septic tanks are designed of triangular form in order to facilitate deposition of sludge. They will be constructed by excavating the necessary amount below ground level. At the apex of each triangle and for the whole length of a tank a perforated sludge pipe is provided with the object of permitting of the periodical removal of sludge without interruption to the working of the tank. The inlet and outlet pipes of the tanks are turned down to prevent disturbance of the scum, or surface layer of contents. The sludge will be removed from a tank by opening the sludge valve which will allow the sludge and a certain amount of liquid to pass into a sludge well which is shown in plate 219. From the sludge well the contents will be lifted by a hand chain pump to a cistern where the sludge will settle and the excess liquid will flow back into the septic tanks. Bacterial filters: These filters will be two in number and will measure each $36' \; 4'' \times 30' \times 6'$. They will be constructed of rough stone outer walls with a filling of broken stone, vitrified engine ashes or other suitable materials as may be available at the time of construction. It will be advisable to fill one filter with, say, broken stone and the other with vitrified engine ashes or vitrified broken bricks in order to test results by analyses of effluent. The distribution arrangements will be the well known Stoddart's distributors which are suitable for institution disposal works. Other types of distributors will not be so suitable from the point of view of maintenance and supervision. The type adopted is one which requires hardly any attention or repairs. The plan of the filters is shown in plate 214. The filters will be excavated below ground, a suitable space around them being also excavated for aeration purposes. The floor will be of concrete plastered with cement and an effluent drain will surround each filter. Effluent: The effluent from the filters will either be led away by a 12-inch stoneware pipe to the Ottary nullah or it will be led to a suction well and pumped therefrom on to a sewage farm by a centrifugal pump and oil-engine. The design for the engine-house will be found in plates 217 and 218. Sewage farm: Besides the area required for the disposal works an additional area has been marked out

for a sewage farm, if required. This farm is located on land partly open, partly burrow pits, and partly covered with trees, scrub jungle, prickly pear, and huts forming a paracherri. The soil is not suitable for a farm for treating raw sewage but the effluent from the filters can be utilised in growing grass, cholam or vegetables. The farm is underdrained, each underdrain discharging into an effluent channel which will convey the final farm effluent to the Ottary nullah."

Bacterial Filters For Street Drainage: Plate 207.

In the above plate is illustrated the type design No. 110 issued with proceedings of the Madras Sanitary Board No. 96-S., dated 9-3-1911. The specification report which accompanied this design was as follows: These bacterial filters are intended for purifying the sewage of three or four streets in a small town so as to prevent to a considerable extent the fouling of the river into which the street drains discharge. 2. At a suitable site near the river bed and elevated above it at least 5 or 6 feet and above ordinary flood level if possible, there will be constructed at the end of the open street drain, a catch-pit and two or more bacterial filters. 3. The sullage which arrives at the end of the open street drain will be turned by a weir placed across it into a catch-pit. This catch-pit will usually measure 4′ × 2′ 6″ and the pit itself will have its bottom 12″ below bottom of drain. The pit will be divided into two portions by a division wall $4\frac{1}{2}$ inches thick and 3 feet long. 4. In the catch-pit the sand and stones brought down by the street drain will be deposited and the catch-pit will require to have these stones and the sand removed therefrom daily. 5. The sullage will re-enter an open drain through a screen which will catch all floating debris and will pass on to the two or more bacterial filters. 6. The bacterial filters will consist of open excavations to a depth of 4′ 6″ below level of bottom of drain, which excavations will be filled in with broken stone or vitrified brick in sizes ranging from 4″ to $\frac{1}{2}$″, the larger size being at the bottom. The bottom of excavation will slope towards the centre at 1 in 40 and along the centre line will be laid an open jointed stoneware pipe. The outlet from the bacterial filter will be by a 4-inch cast iron sluice valve built in a valve chamber of $4\frac{1}{2}$ inch brick walls. In continuation of the valve chamber there will be a line of 4-inch stoneware pipes as far as the bed of the river. 7. The number and area of bacterial filters will depend on the extent of land available and on the condition that the total volume of stone filling is equal to one and a half times the quantity of sewage to be treated during the dry weather. The surface of each bed will be formed into channels by making slight depressions in the filled-in material. 8. Working instructions: Catch-pit: All deposited material found in the bottom of the catch-pit will be cleared out daily and removed to rubbish depot by conservancy cart. The screen will also be often examined and floating debris removed three or four times daily by the man in charge of filters. Bacterial filters: These will be worked in the following manner: In the evening at 7 o'clock the plank shutter on the drain opposite an empty filter will be opened so that the night flow of sullage, if any, will run into filter. In the morning this filter will fill up and when it is full the plank shutter will be replaced and sullage turned into next empty filter by man-in-charge who will remain daily on the spot. The filter which has already been filled will remain standing full for at least two hours and at the end of this time the 4-inch sluice valve on the outlet pipe will be slowly opened and contents of filter discharged into the river bed, which discharging should take from 1 to 2 hours. The filter when empty will remain so for two hours at least, at the end of which time the filter will be ready for recharging. From the time taken in the operations it will be observed that each filter will be used twice daily, and on this basis the size of filter has been fixed. 9. When a filter becomes choked, which will occur after, say, a year's working, the broken stone should be removed and washed with river water. The washing should take place either at the catch-pit or above the drains so that the washings can be treated in the working bacterial filter. 10. The installation is a simple and inexpensive one and the working should be satisfactory, provided the catch-pit is regularly cleaned and the bacterial filters are worked as directed.

Abstract Of Quantities For Bacterial Filters: Plate 207.

Quantity.	Description of work.
2,876 c. ft. ...	Earthwork, excavation.
1,148 „ ...	Forming banks.
28 „ ...	Concrete, in surkhi mortar.
55 „ ...	Brickwork in do.
133 sq. ft....	Plastering with cement, $\frac{1}{2}$″ thick.
10 „ ...	Cuddapah slabs, $1\frac{1}{2}$″ thick, pointed with cement.
2 No. ...	Plank shutter.
1 No. ...	Iron grating.
2 No. ...	4″ sluice valves including erection.
0·988 cwts. ...	4″ flanged pipes including laying and jointing.
76 r. ft. ...	4″ stoneware pipes.
76 „ ..	Laying 4″ stoneware pipes.
26 No. ...	Cement joints.
891 c. ft. ...	Stone filling varying from 1″ to 4″.
12 „ ...	Cutstone work.
79·50 r. ft. ...	12″ open drain.
	Add 5 per cent. for breakages for stoneware pipes.
	Total Rs.

A Septic Tank And Filter Bed For The Purification Of Sewage: Plates 208 And 209.

In the above plates are illustrated the type designs Nos. 164 and 164-A issued with proceedings of the Madras Sanitary Board No. 24 S., dated 9-1-1915. The specification report which accompanied these designs was as follows: The type design is for an installation for the biological treatment of 5,000 gallons of sewage per day. It embodies the most approved practice of the present day subject to the limitations imposed by the necessity for cheapness and simplicity of working in all sanitary measures intended for communities and institutions in this country. 2. Principles of bacteriological purification. Some little knowledge of the biological action which effects the purification of sewage is useful as it will enable the man-in-charge to work the septic tank and filters all the more intelligently and efficiently. 3. All sewage contains within itself the necessary organisms for its own purification. These organisms are of two kinds: anaerobic and aerobic. The anaerobic bacteria live and multiply in sewage in the absence of free oxygen, whereas the aerobic bacteria require free oxygen for their sustenance and growth. Sewage undergoes two changes when it is purified with the aid of these organisms. The first part of the process consists in the decomposition and liquefaction of the solid organic matters and their resolution into simple forms. The second part of the process consists in oxidation and nitrification. 4. If a quantity of sewage is discharged into a shallow pit and left undisturbed, that is, if it does not receive an addition of fresh sewage every day, it will undergo a process of natural purification. The liquid will soak into the soil and gradually disappear, and the solid organic matter will be broken up, oxidized and nitrified, and finally all that will be left of the sewage in the pit will be a residue similar to that of the humus of the soil. This change is effected by bacteria contained in the sewage itself. The biological treatment of sewage seeks to effect these changes in a cheap, quick and efficient manner. 5. Component parts of a bacterial installation: The elements of a complete bacterial installation, which is now recognised as being the most efficient, are: (1) grit chamber, (2) screening arrangements, (3) septic tank and (4) percolating beds. Indian sewage contains proportionately more earthy matter, and harmless vegetable matter like leaves than the sewage of European towns. If these matters are not eliminated by a preliminary treatment they clog up filter beds and reduce their efficiency. 6. Capacity of the works: The determination of the quantity of sewage to be treated is an important point as on the quantity of sewage will depend the size of the installation. There are objections to making the plant too large, as there are to making it too small. The existing surface drains are storm water carriers with a capacity of 50 to 200 times the dry weather flow. The only correct method of calculating the quantity of sewage to be treated is to gauge the flow at outlet, and as much as 50 per cent. may be added for increased flow during festivals. In preparing plans for an installation in connection with any new scheme of drainage the quantity of sewage may be assumed to be equal to the water supply, which is usually assumed to be $2\frac{1}{2}$ gallons per head per diem in towns where there is no piped water supply. 7. Grit chamber and screen: In the type design the sewage from the outfall sewer first enters a small silt-pit. Owing to the increased cross sectional area of the silt-pit, the velocity of the passage of sewage through it is diminished and this induces the deposition of silt for which a depression is provided in the pit. As the sewage issues out of the pit it passes through a slanting screen. In small installations the width of the silt chamber should be $2\frac{1}{2}$ times the normal width of the drain and the length not less than twice the breadth. The screen occupies the full width of the chamber, and consists of $\frac{1}{2}''$ iron bars placed $\frac{3}{4}''$ apart and fixed in angle iron frames. In larger installations the rule is to make the chamber large enough to reduce the velocity of flow through it to not more than 5 feet per minute and its length 2 or 3 times the breadth as calculated above. 8. Septic tank: The capacity of septic tanks should not be less than 12 hours' supply or in the present case one-half of 5,000 gallons. The most efficient depth for septic tanks is 5 or 6 feet. In very large installations they are made with an effective depth of as much as 9 feet, but this seems to be with the object of economising space and not because of any better efficiency. The tank should be $2\frac{1}{2}$ times as long as it is broad. 9. A cardinal principle in the construction and working of a filter bed is that the sewage should be admitted, and that it should travel along a plane 15 to 24 inches below the surface of water in the tank as it is very essential for the satisfactory working of septic tanks that the scum which forms on the surface as well as the sludge at the bottom should be disturbed as little as possible. This is effected in the design by providing bends at the inlet and the outlet, the mouth of the bends being 15 inches below the low water level in the tank. 10. The septic tank is not covered. It was once considered that anaerobic bacteria could only flourish in closed tanks, but that idea is now obsolete; and it is now established that they can do their work in an open tank as well as a closed one. 11. The floor of the septic tank slopes to a valve chamber with a fall of 1 in 60. When sludge accumulates in the septic tank, it can be removed by coolies and discharged into the sludge pit from which the liquid

flows back through the overflow drain into the grit chamber and the sludge is carted away. Any fine silt that remains at the bottom of the tank may be discharged into the storage well by scouring through the scour pipe, by opening the valve. From the storage well sludge will be lifted by buckets and spread over shallow pits where the liquid will soak into the ground and the residue will be a harmless matter resembling the humus of the soil. 12. Storage well: In the majority of cases in the plains sufficient fall of ground will not be available to work a bacterial installation by gravitation. A collecting well and some arrangement for lifting the liquid becomes necessary in such cases. Some lifting arrangement had better be interposed between the septic tank and the filter, as it enables the latter to be placed wholly above ground, a condition which has many advantages. 13. The storage well has a capacity of 2,950 gallons or a little more than half the quantity of the sewage to be treated The lifting arrangement is a piccottah, which is the simplest and cheapest lifting appliance when liquid within the limits of its capacity has to be dealt with. The bailing process should be regular so as to secure an even rate of discharge on the filter. The duration of bailing should be as long as possible but not less than 12 hours. 14. Percolating filter: The percolating filter consists of a concrete platform raised a little above ground level and sloping from its centre to the sides which are surrounded by a drain for collecting and carrying away the effluent. 15. The filtering medium will consist of a heap of broken stone laid over the concreted floor and prevented from sliding down at the sides by retaining walls of dry rubble. Broken granite forms the best filtering material. The stone should be broken to pass a ring $\frac{3}{4}''$ in diameter. 16. The masonry pillars at the corners and the intervening space serve a double purpose. They give support to the retaining walls and serve to carry the distribution channels. 17. The system of distribution consists of a wrought iron rectangular trough resting on the masonry pillars along one side of the filter with V channels branching off from it. The V channels are perforated at the bottom with one-eighth inch holes. The blind ends of the V channels rest on the opposite row of pillars. 18. Cost: The estimated cost (at Madras rates) of the installation is as follows:

			Rs.
Silt pit, septic tank, etc.	...	...	600
Storage and piccottah well	...	...	510
Percolating filter	...	...	600
		Rs.	1,700
Supervision, $2\frac{1}{2}$ per cent.	...	...	127
Contingencies, 5 per cent.	...	...	63
	Total Rs.	...	1,900

The cost may be taken to vary from Rs. 1,900 to Rs. 2,850 according to the locality. 19. Conclusion: The best method of treating the ordinary sewage of town and villages in Southern India where the dry scavenging system prevails is sewage farming, provided of course that suitable land is available. The requirements of suitable land for sewage farming are that the soil should be light and sandy and that it should be free from liability to be flooded. Where these conditions cannot be secured the installation of bacterial works is indicated. Experiments made at the King Institute, Guindy, have proved that filtered sewage has no higher value as manure than crude sewage. Owing to the absence of night-soil in the sewage and the high temperature of Southern India, nitrification takes place rapidly when sewage is spread on the ground. The ultimate result of treating sewage bacterially is its nitrification.

Abstract Of Quantities For Septic Tank, Filter Bed, Etc., For The Purification Of Sewage. Plates 208 And 209.

Quantity.	Description of work.
	General Abstract.
	Silt pit, sludge pit, valve chamber and septic tank.
	Storage and piccottah well.
	Percolating filter.
	Contingencies at 5 per cent.
	Petty supervision at $2\frac{1}{2}$ per cent.
	Total Rs.
	Silt pit, sludge pit, valve chamber and septic tank.
2,200 c. ft. ...	Earthwork, excavation.
410 „ ...	Concrete, broken brick in surkhi mortar.
689 „ ...	Brickwork in surkhi mortar.
743 sq. ft. ...	Cement plastering, $\frac{1}{2}''$ thick.
120 „ ...	Do. $\frac{3}{4}''$ do.
83 lb. ...	Wrought-iron work for grating.
	Regulating shutters including cast iron small pipe, pins, etc., to adjust the shutters complete.
5·11 cwt. ...	6″ cast iron pipe, 9 ft. long, with spigot and socket end.
2·64 „ ..	6″ cast iron special pipe bend.
2·928 „ ...	4″ scour pipe, 9′ long.
No. 1 ...	6″ cast iron pipe, $1\frac{1}{2}'$ long.
„ 1 ...	Do. do. $1\frac{1}{3}'$ do.
„ 1 ...	4″ sluice valve with rods including fixing, etc.
„ 1 ...	4″ special pipe, 3 feet long.
„ 1 ...	4″ pipe in wall of septic tank, $2\frac{1}{2}'$ long.
„ 1 ...	Do. storage well, $1\frac{1}{2}'$.
„ 2 ...	Puddle collars, 4″.
„ 1 ...	Percolating shutters at the head of 6″ overflow drain in sludge pit.
	Laying and jointing pipes.
	Sundries.
	Total Rs. ...

Quantity.	Description of work.
	Storage and piccottah wells.
1,100 c. ft. ...	Earthwork, excavation.
260 „ ...	Concrete, broken stone in surkhi mortar.
690 „ ...	Brickwork in surkhi mortar.
80 sq. ft. ...	Cement plastering, ¾" thick.
565 „ ...	Do. do. ½" do.
No. 1 ...	Piccottah, wood, bamboo, bucket, etc., complete.
60 r. ft. ...	Old railposts, clamps, etc., complete.
5·11 cwt. ...	Cast iron pipes, 9' long.
1·464 „ ...	Cast iron bends in piccottah well.
No. 1 ...	Cast iron specials, 4' long.
„ 1 ...	Cast iron pipes, T-shape.
	Laying and jointing pipes.
	Sundries.
	Total Rs. ...
	Percolating filter.
550 c. ft. ...	Earthwork, excavation.
530 „ ...	Concrete, broken stone in surkhi mortar.
360 „ ...	Brickwork in surkhi mortar.
278 sq. ft. ...	Plastering with cement, ¾" thick.
460 „ ...	Do. do. ½" thick.
410 c. ft. ...	Dry rough stone facing.
815 „ ...	Dry stone filling.
No. 1 ...	T-iron pipe for percolating filter at D.
340 lb. ...	Galvanized plate iron trough for percolating filter.
360 „ ...	Perforated iron V channel.
No. 6 ...	Wrought iron flanges.
101 lbs. ...	Do. seats.
200 r. ft. ...	Forming overflow channels.
110 „ ...	Do. sub-carrier.
70 „ ...	Do. bund.
	Chamber at the end of effluent drain.
	Laying and jointing pipes, etc.
	Sundries.
	Total Rs.

A Pail Depot: Plate 204.

In the above plate is illustrated the design for a Pail Depot based on design by Mr. W. E. Buchanan, Engineer in charge of Water and Drainage Works, Simla Municipality, as drawn up by Mr. Hutton, Sanitary Engineer, Madras. The specification report which accompanied this design was as follows: General: In order to dispose in as sanitary a manner as possible the night-soil in a town which possesses an efficient system of pipe sewers it is necessary to provide pail depots owing to the fact that very few owners of houses in an Indian town go the expense of providing flushing latrines or other sanitary arrangements in their houses. The general idea of a pail depot is that the sweeper will collect the night-soil in pails from each house and will convey them to the pail depot. The pail depot simply consists of a special pattern of water closet sufficiently large to deal with the quantities of solid matter brought to it by the municipal sweepers. In other words, instead of each owner of a house providing a water closet in that house the municipality provides a municipal water closet which is capable of dealing with the night-soil with a large number of houses. The actual number of houses which can be dealt with cannot at present be definitely stated as this will greatly depend on the custom of the particular town, and the number of house latrines contained in it. The type of pail depot which is described in this specification is practically the same as that used at Simla the details of which were designed by Mr. Buchanan, the Engineer in charge of water supply and drainage works of that municipality. These pail depots have been invented by him and found to be efficient and they can be recommended for towns in this Presidency possessing a pipe water supply and an efficient sewerage system. Building: The building to contain the pail depot consists simply of a corrugated iron structure of inside dimensions 10′× 6′9″. The building is constructed of wooden posts and corrugated iron walling and two windows are provided one to give light to the cast iron receptacle and the other to give light to the inspection chamber of the syphon trap. The outside of the building can be painted chocolate colour in the plains and emerald green at Ootacamund the same colour as the existing ventilating shafts. Basement: The basement of building is built of brick in chunam, the cast iron receptacle and syphon trap being embedded in concrete as shown in the plan. The floor of the building slopes to a central point provided with a grating in connection with the inspection chamber. The floor itself is made of Cuddapah slabs with joints neatly made and pointed to the full depth of the slab. Superstructure: Around the plinth of the building as shown in the plan there is a masonry wall, 6″ in height, plastered with cement. The object of this wall is to prevent spill water from overflowing on to the ground from the building when the floor is being washed by the canvas hose in connection with one of the flushing tanks. Above the masonry wall there will be a strip of expanded metal around the building to serve as an inlet ventilator to the building. The outlet ventilation will be provided by the provision of expanded metal in the gables of the building. The whole of the gables will be filled in with expanded metal as it is essential that the building should be well ventilated. Receptacle of night-soil: The arrangement for the disposal of the night-soil consists of a cast iron receptacle 2′ in diameter the bottom of which is curved and reduced in size to 6″ in diameter. The section of this receptacle is shown in the plan. In the position shown there will be an expanded metal screen resting on 4 legs cast in one piece with the receptacle. This expanded metal screen will be kept in place by 4 clips fastened to the receptacle by studs with the

object of preventing the sweepers from removing the screen. The screen mentioned is made of expanded metal, the spaces of the expanded metal being about 2" by 1". If the screen were not provided and pails of night-soil were dumped into the receptacle the sewer would get choked. The object of the screen is to retain the night-soil when it is dumped in from the pails and by means of a 2½" canvas hose, the sweeper in attendance is enabled to wash the night-soil through the ground down the receptacle and so down the sewer. In other words, the night-soil is liquefied sufficiently to obviate any blockage either in the receptacle, in the syphon trap or in the sewer connecting with the municipal main drain. The cast iron receptacle has been specially designed by Mr. Buchanan, the Engineer of the Simla Water Supply and Drainage Works, and it is made by the Vulcan Iron Company of Calcutta who alone possess the patent. The cast iron receptacle should therefore be obtained from this firm who possess all the rights of the design. Flushing: Outside the building two 100 gallon tanks are provided at an elevation of 8′ above ground. One of these tanks is intended for supplying through a quick action lever sluice valve a two inch pipe connection to the end of it. A short length of 2½" canvas hose is attached to the end of the two inch iron pipe with the object of flushing the cast iron receptacle. The other tank is an automatic tank provided with a 4" outlet pipe and is intended to automatically flush out the cast iron receptacle and also the 6" sewer leading from it, without requiring the attendant to open valve in order to turn on the flush. The supply of this tank from the service main can be regulated to give the requisite number of flushes as determined by actual working conditions. Pails: The pails used at Simla are galvanized iron drums about 10 or 12 inches in diameter and 18 inches high similar to paint or oil drums. Two handles are provided on the side of the drum and a lid with a handle for removal. The actual size of the pails which will be used at Ootacamund will be determined by trial. The pails will be washed by the hose in the depot. One attendant will be required to be in attendance at each depot when the depot is being used. Probably one of the municipal sweeper staff will be employed. Conclusion: The provision of these pail depots or dumping pits is a sanitary measure of great importance. They permit of the abolishing of the night-soil carts which are not only sanitarily objectionable but are also expensive in use.

Abstract Of Quantities For A Pail Depot: Plate 204.

Quantity.	Description of work.
146 c. ft. ...	Earthwork, excavation.
98 „ ...	Concrete, broken vitrified brick in chunam.
104 c. ft. ..	Brickwork in chunam.
108 sq. ft. ...	Plastering with cement, ½" thick, (1 : 3).
63 „ ...	Flooring with 1½" Cuddapah slabs over 4" concrete and pointed with cement to full depth of the slab.
36·80 c. ft. ...	Country wood, wrought and put up.
352 sq. ft. ...	Roofing and walling with corrugated iron sheet (20 B.W.G.) including ridging, etc., complete, without reepers.
2 No. ...	Wooden finials, complete.
23 sq. ft. ...	Door with corrugated iron sheet including teak frames, etc., complete.
18 „ ...	Windows, glazed, with teak frames, etc., complete.
47 „ ...	Expanded metal screen with teak beading, fixing, etc., complete.
17 No. ...	Stone slabs.
Sum ...	Tank stage with 1½"×1½"×¼" angle iron post bearers, 1½"×1¼" ties, erection, etc., complete.
Sum ...	100 gallons tank with ball valve, quick action lever sluice valve 2 inches, 2" wrought iron tubing up to cast iron receptacle including 2½" canvas hose, fixing, etc., complete.
Sum ...	100 gallons automatic flushing tank with ball valve, cast iron piping up to cast iron receptacle including fixing, etc., complete.
Sum ...	Wrought iron service pipe for two tanks including laying, jointing, etc., complete.
1 No. ...	Cast iron receptacle with expanded metal grating, fixing, etc., complete.
1 No. ...	6" stoneware syphon trap including fixing.
1 No. ...	6"×6" stoneware branch.
1 No. ...	6"×4" do. do.
3 No. ...	6" plain pipe.
2 No. ...	4" plain pipe.
2 No. ...	Stoneware ¼ bend.
1 No. ...	Manhole cover, clear opening, 18" × 18" No. 300, page 115 of Messrs. Ham Baker & Co.'s catalogue dated January 1905 including fixing, etc., complete.
1 No. ...	Cast iron cleaning eye with cover including fixing.
1 No. ...	Cast iron grating including fixing.
1 No. ...	Sewer ventilating shaft 4" diameter: cast iron ground base, 2 feet deep with welded tube including coronet and copper wire cage as per No. 498, page 174 of Messrs. Ham Baker & Co.'s catalogue, dated January 1905; height out of ground is 20 feet.
Sum ...	Fixing shaft in concrete bed, stoneware pipes, ¼ bend, including laying, jointing and excavation complete.
942 sq. ft. ...	Painting, 2 coats with chocolate and emerald green.
	Establishment charges.
	Unforeseen works.
	Total Rs.

Sewage Farms.

After the sewage is rested in a septic tank, the sewage is usually treated on land in what are called sewage farms. A sewage farm then is the plot of land in which the necessary water for cultivation is sewage. Irrigation of sewage farms is divided into three classes, 1. catch water system, see fig. 8, plate 221. 2. intermittent filtration, ridge and furrow system, see fig. 9, plate 221 and 3. broad irrigation, ridge and furrow system, see fig. 10, plate 221. In broad irrigation, the sewage is distributed so as to flow gently over ample surfaces of land, sufficient for its absorption and purification. In intermittent filtration, the sewage is discharged at intervals in large volumes, over specially prepared levelled surfaces of land through which the sewage filters, the filtrate in such cases is treated by being carried away through a porous soil or by a system of sub-soil drainage. In this system of sewage irrigation, the sewage farm land cannot be used for irrigation continuously and must have periods of rest. As a rule, provision of sub-soil pipes for the conveyance of extra sewage should be provided; however, if the soil of the sewage farm is a porous one, sub-soil drains are not necessary. In the case of broad irrigation, the object of sub-soil drains is to prevent the area being water-logged. In the case of intermittent filtration, the sub-soil drains are laid with the object of collecting and carrying off the whole of the filtered liquid. A sub-soil drain consists of small pipes laid usually at intervals of 33 feet and jointed together loose or wedge jointed. The sewage after standing at rest on the plot of land is found to have wetted the area required and there is a certain amount of excess not required for the farm which is drained by the sub-soil drains. The object of a sewage farm is purification of sewage. A soil in which the best crops are obtained under irrigation and the income from the sale of which is encouraging is not to be supposed as the best soil for sewage purification purposes. So, the selection of a site for a sewage farm should depend on the character of the soil as regards its purifying effects. In the order of suitability of the soils for sewage purification purposes, soils may be classified thus: The best soil is a sandy loam, that is earth with a mixture of sand. Peaty soils, that is earth in which there is not so much of sand, have been tried and found to give good results. Pure sand is not considered suitable for sewage farming but sometimes sewage farms have been laid out on such soils. The worst soil for sewage farming is stiff clay and this should never be employed for sewage treatment. There is no use of attempting to treat sewage in a land where the sub-soil water level is high; but, in some cases, if we are compelled to adopt such land, permanently lower the sub-soil level so that the sewage let on sewage area is effectively purified. Area of land required for treatment: For conditions of England, the area required for sewage farming is fixed as follows: One acre for 100 of the population, which is based on the presumption that the quantity of sewage used is 40 gallons per head per day or in other words the proportion of area for sewage farming is taken to be one acre for 4,000 gallons. This provision is probably necessary for the climatic conditions of England. For Indian conditions, where the temperature is usually high, a provision of 10,000 gallons per acre is usually made. This provision is only where the sewage does not undergo any prior treatment; if the sewage passes through purifying beds, the usual provision is 30,000 gallons per acre. 25% of the area required is added for the area of the sewage farm for recuperative purposes. Laying a sewage farm: Divide the area selected for sewage farming into plots of land. As a rule, sewage farms are laid exactly at $\frac{1}{10}$ of an acre or $66' \times 66'$; where sub-soil drains are necessary they are laid at intervals of 33 feet. The area of a plot of ground, *viz.*, $\frac{43560}{10}$ sq. ft. is the net area exclusive of bunds and channels. The selection of a site for a sewage farm depends on the following considerations: 1. The highest point in the sewage farm should be low enough for the sewage to flow to it by channels laid with a suitable grade. 2. The lowest point in the sewage farm should be high enough to permit of the flow of sewage after reaching the lowest point to be discharged into a water course through sub-soil drains. This second condition necessitates the existence of a water course bordering the sewage farming site into which may be diverted the excess flow of sewage not required for farming purposes and the effluent from sub-soil drains. 3. If a water course does not exist on the borders of the sewage farm, then provision should be made for a channel to convey the surplus effluent from sub-soil drains to the nearest water course. 4. The farm and its sub-soil drains should be above the level of ordinary floods. 5. The soil should be suitable. 6. The surface should be gently sloping with broad even features and free from depressions where the sewage is ilkely to pool. 7. The farm shall not be on the windward side, usually for the Presidency of Madras a site north-west of town is generally suitable. 8. It should be neither too far nor too near the town. 9. There should be sufficient area for the treatment of the sewage. An artificial method to make unsuitable soils fit for sewage farming is to throw the rubbish of a town for a number of years at least to a height of $1' 6''$. The outcrop from an area so treated has produced excellent results, *i.e.*, Rs. 360 per acre. The average net income from

sewage farms is Rs.200 per acre in the city of Madras. Indian sewage is more difficult to be treated than sewage in England as people here use oven ashes for the washing of vessels, and Hindus use cowdung for the washing of floors; old rags and vegetable matter are thrown indiscriminately into drains and sewers. Further, as land for the requirement to treat the sewage in the corporations of the West is either scarce or unsuitable, methods of treatment other than the one on land are usually resorted to in Western countries. In most cases, suitable land with area necessary for the requirements of a farm is obtainable in India and therefore the only provision necessary for Indian conditions is apparently a sewage farm on which will be treated the sewage in its crude or raw state or the sewage after treatment in septic tank. The provision of septic tanks should necessarily be made in cases where the sewage includes also the excreta of the population. In cases where land is not available, filter beds or contact beds are used. Proper crops to be grown on sewage farms: hariali grass, potatoes, sugar-cane and English vegetables in cold climates. In some of the small sewage farms, plantains and brinjals have been tried but have not been very successful. At Ootacamund lucerne and potatoes yield a good crop. In the city of Madras the chief crop is the hariali grass which is a paying concern for city conditions. For conditions in the plains, sugar-cane is the best crop, as arrangements can be made for its conversion into jaggery and sugar.

Government Technical Examinations: 1904.

Time: Three hours: Nine questions should be answered of which one, at least, must be from each section: I. General: 1. A drain 100 feet long and 12 inches wide and 18 inches deep is proposed to be constructed, with vertical sides and semi-circular bottom, as shown in the sketch, fig. 3 in plate 222. If the only materials to be used in the construction of the drain are concrete in chunam, granite stone coping, and cement plaster, make an estimate of the quantities of (1) excavation, (2) concrete in chunam, (3) granite stone, (4) cement plastering. 2. A well is $12\frac{1}{4}$ feet in diameter to outside of the parapet wall and the platform is 6 feet wide and 9 inches thick. Estimate the cubical contents of the concrete platform. II. Buildings: 3. Give all the qualities of a good brick. What quantity of moisture does a good brick absorb? 4. What is the object of a damp proof course? Give a sketch (cross section) showing the proper position of a damp proof course in the wall of a building. State the various materials which may be used for a damp proof course and the proper thicknesses of the same. 5. What is surkhi? Give the usual proportions of mortar containing it. What is the object of screening slaked lime? State how you would test sand to be used in making ordinary mortar. 6. Give a complete specification for a cement plastered concrete floor for a 4-bed ward, giving thicknesses and proportions of concrete and cement plastering and stating how the floor should be laid. III. Water supply: 7. A built-well is 10 feet in diameter and 25 feet deep from the parapet to the bottom of the well. The bottom 10 feet is in a water-bearing stratum. Make a typical cross section of one side of the well showing the proper method of construction and explain shortly how the well should be constructed. 8. Give the formula you would use to find the discharge of water from a pipe. What is the discharge from the 2 inch pipe shown in sketch, fig. 4 in plate 222, the level of water in the tank remaining the same. 9. Describe fully the method of taking a sample of water, from a disused well for chemical analysis. IV. Drainage: 10. The width or diameter of a semi-oval drain is 12 inches and the radius at the invert is one-eighth diameter. Give a sketch showing the dimension necessary for drawing the cross section of the drain. Why are drains of above section usually recommended to be plastered on the inside with cement? State the advantage of a semi-oval drain from a sanitary point of view. 11. Describe the method of jointing glazed stoneware pipes used for carrying sullage water. Illustrate your answer with a sectional sketch of half a joint. What is the object of gasket or spun yarn, and what invariably happens if it is left out? 12. What do you understand by the term "self-cleansing velocity?" Give the self-cleansing velocity required for an open masonry drain, a 4-inch, 6-inch and 12-inch pipe sewer. How should the junction of a 9-inch open masonry drain with a 15-inch open masonry drain be carried out if the direction of flow in the latter is at right angles to that in the former? Illustrate your answer by a sketch. V. Disposal of Sewage: 13. What conditions are most suitable for starting a sewage farm near a small Indian town of 9,000 inhabitants which is provided with fairly good open drains? If the town's supply of water is provided from wells, state approximately the minimum area of land required to dispose of the sewage effectively by irrigation, the nature of the soil being suitable. An open drain carrying sullage water from a large house, built on stiff loam and having the benefit of a piped water supply, ends in a small open cesspool, which on overflowing causes a nuisance. It is impossible to extend the drain except at prohibitive cost. Explain fully the arrangement you would propose to effectually purify the sewage and remove the nuisance.

Government Technical Examinations: November 1905.

Time: Three hours: Eight questions should be answered, of which one at least must be from each section: I. General: 1. Draw the cross section and plan of a cesspool, suitable for an ordinary house, to a scale of 1 inch to the foot. What additional requirements would you propose for a cesspool for an institution? 2. Estimate the quantities required for the cesspool you are asked to draw in question 1. 3. The following extract from a level book shows the readings taken for a proposed masonry drain in a street. Complete the book and state the fall available for the proposed drain.

Back.	Inter.	Fore.	Rise.	Fall.	Reduced level.	Distance in feet.	Remarks.
5·21					100·00		B.M.
	6·38			1·17		0	Beginning of proposed drain.
	6·71			·33		100	
4·89		7·04				200	
	5·22					300	
		5·55				400	End of drain.

II. Buildings: 4. State what parts of a brick-in-mud building are built in brick in chunam, and why it is advisable to use brick in chunam in those parts. 5. State what thicknesses of walls up to 27 inches can be built with ordinary bricks, and give a sketch of two courses of bricks in a 9-inch wall. 6. Sketch showing the wall plate, a coupled rafter for a span of 9 feet and also for a span of 13 feet. What is used instead of coupled rafters when the span is 16 feet or more? 7. What precautions would you adopt in designing a building in order to ensure the best possible ventilation? What is the object of foundations, and how do you ascertain their proper depth? III. Water supply: 8. State how you would test and report the yield of water from a well. What is the head of inflow and what is its limiting amount in sandy soil and rock? 9. Give a cross sectional sketch of an ordinary hand-lift pump suitable for pumping water from a well and describe its action. What is the theoretical and practical heights the pump barrel can be placed above the water level? 10. In what soils would you propose to construct a sunk well? Describe the method of constructing such a well. IV. Drainage: 11. A street drain is 9 inches wide and 12 inches deep and has a fall of 1 in 300. Supposing the bottom semi-circular and the sides vertical, what is the discharge of the drain when it is running full? 12. What provision would you make for the discharge of rainfall by open street drains on (1) the east and (2) west coast of this country? Would it be necessary to consider also the quantity of sewage? V. Disposal of sewage: 13. Mention the different methods of sewage disposal and state which you think is most suitable for Indian towns. Make a sketch plan of a small sewage farm. 14. Sketch and describe a make-shift method for disposal of small quantities of sewage, land not being easily available.

Government Technical Examinations: November, 1906.

Time: Three hours: Seven questions only should be answered. 1. Make a sketch to any suitable scale of the cross section of a roofed masonry cistern, inside bottom width 10 feet, suitable for storing drinking water to a maximum depth of 4 feet 6 inches. 2. Suppose the cistern in question 1 is 20 feet in length inside at bottom, estimate the quantities of the cistern omitting roof. 3. The following is a statement of levels taken for a street where it is proposed to lay a pipe sewer 6 inches in diameter and at a gradient of 1 in 60:

Back.	Inter.	Fore.	Rise.	Fall.	Reduced level.	Distance in feet.	Remarks.
5·42					100·00	0	Beginning of 6-inch sewer.
	5·03					100	
5·84		5·96				200	
	6 63					300	
		7·01				375	End of 6-inch sewer. joins 9 inch sewer;

If the depth of sewer below ground at the beginning is 3 feet 6 inches, what is the depth of sewer at its junction with the 9-inch main sewer? Show all calculations and complete the statement of levels. 4. Sketch a king post truss, suitable for a span of 25 feet. Show usual dimensions. 5. Describe in detail how a floor for a one-storied public building should be constructed. 6. What is the discharge of a 4-inch pipe, 1,000 feet long, supposing there is a constant cistern water level of 10 feet over the inlet of the pipe and the ground in which the pipe is laid falls at the rate of 1 in 500 away from the cistern? 7. Show by a diagram what you understand by the terms quarter, one-eighth, and one-sixteenth bends when referring to pipes. 8. Draw to any suitable scale a 9-inch oval surface drain suitable for carrying sullage water. 9. Make sketches and describe the latrine which you consider best for mufassal towns and mention all practical defects of the type selected.

Government Technical Examinations: 1907.

Time: Three hours: 1. Draw (any scale) the elevation of king post truss for a span of 20 feet. 2. Estimate the work above. 3. Sketch the position of damp proof course in the walls of hospitals and state the materials used. 4. What are the different kinds of roofs used in this country? 5. What is the usual proportion of surkhi mortar and state how it can be locally determined. 6. Find the discharge of a street drain of 12″ the bottom of which is semi-circular, sides vertical, fall 1 in 500, depth of water 9″? 7. What are the different methods adopted in India for purifying sewage?

Government Technical Examinations: June, 1908.

Time: Three hours: Seven questions only should be answered. 1. Draw to a scale of 4 feet to an inch the plan and section of a well fulfilling the following conditions: Sub-soil: sandy. Summer water level: 9 feet below ground. Depth of well: 14 feet below ground. Diameter of well: 6 feet. Thickness of brickwork in steining: $1\frac{1}{2}$ feet. Platform: $4\frac{1}{2}$ feet wide and of suitable design. Parapet wall 9 inches thick and suitable height. 2. Estimate

the quantities for the following items of work in the above well: (*a*) Brickwork in steining. (*b*) Brickwork in parapet wall. (*c*) Plastering exposed surface of platform. 3. Describe the method of measuring a chain line, which is obstructed by a building, both ends of the line fig. 5, plate 222 being accessible. 4. Write a full specification for plastering a new cesspool with Portland cement, giving the proportions of ingredients in mortar, the thickness of plaster, the method of applying it, and the precautions and measures necessary for sound work. 5. Describe fully the method of making an ordinary terraced roof. 6. Sketch the ground plan of a three-bed ward for general diseases showing position and size of beds, windows and doors. What is the requisite minimum (*a*) height of a ward, (*b*) cubic capacity of space per bed for general diseases, and (*c*) cubic capacity of space per bed for infectious diseases. 7. Find the discharge in cubic feet per minute from a triangular-shaped drain 1 foot 6 inches wide and 9 inches deep (as in sketch fig. 6, plate 222) with a fall of 1 in 440 on the supposition that the drain is running two-thirds full. 8. Make a sketch of a syphon flushing cistern and describe its action.

Government Technical Examinations: June, 1909.

Time: Three hours: Seven questions only should be answered: 1. Describe, showing on a sketch the survey lines, how you would proceed to make a chain survey and measure the area of the water-spread of a small irregular shaped tank. 2. Draw to a scale of 4 feet to one inch the cross section of a masonry reservoir, inside dimensions 10 feet wide and 5 feet deep and roof of Mangalore tiles, suitable for storing drinking water in a town. The bottom of reservoir inside to be one foot above ground level. 3. If the reservoir in question 2 is 20 feet long inside, estimate the quantities of brickwork and concrete required in the construction. 4. How would you test and report the inflow of water into a well? 5. Describe tube well and how it is used. 6. How is the size of an open drain in a street determined? 7. What is the discharging capacity of a surface drain 2 feet bottom width, side slopes 1 to 1, fall 10 feet per mile when there is one foot of rain water in it? 8. What is the object of a septic tank? Describe a suitable design for one with sketches.

Government Technical Examinations: 1910.

Time: Three hours: 1. Draw (to any suitable scale) the vertical section of a sunk well, 8 feet in diameter, depth of well 18 feet, depth of summer water level 12 feet. 2. In previous question, estimate the cost of platform at the following rate: concrete in chunam Rs. 12 per 100 cubic feet: cement plastering Rs. 12 per 100 square feet. 3. Describe the various parts of a proper sunk well and explain why they should be provided. 4. Draw to any suitable scale the cross section of 12 inches oval drain. Estimate the discharging capacity of 12 inches drain with 18 inches vertical sides and circular bottom, where drain is full and the gradient is 1 in 500. 5. Draw to any suitable scale the cross section of sand filter, to show the filtering materials and water and describe the action of filter and how it should be worked in practice. 5. Draw the various types of valves used in water supply system. 7. Mention the object of sewage farm in connection with the drainage of a town. Mention the requirements of a suitable farm. 8. With what object is the septic tank sometimes furnished? What is the usual size of the septic tank with reference to the quantity of town sewage

Government Technical Examinations: June, 1911.

Time: Three hours: 1. The reduced levels of the side of a street 1,000 feet long are found to be as follows: At O′, 43·25; at 300′, 41·65; at 550′, 40·19; at 800′, 39·39; at 1,000′, 38·85. What is the gradient of each section assuming a drain is constructed in each of the four sections of the street? 2. A small Mangalore tiled and gabled roofed godown measures 12′ × 8′ inside. Estimate the quantity of teak timber required to roof it. Omit reepers. 3. What is the necessity for digging foundations? Explain how the depth required is determined and what results from insufficient or faulty foundations. 4. Give the area and cubic capacity required for an eight-bed ordinary ward and for a four-bed contagious ward. Why are these dimensions adopted? 5. State the precautions taken to prevent the ingress of polluted surface water into drinking water wells. 6. What is the discharge in gallons per minute of a channel 3 feet wide and 1 foot deep when running full? 7. Referring to question 1, it is proposed to lay a pipe sewer in the street mentioned. For the first 300 feet the sewer will be 6 inches in diameter and thereafter 9 inches. Give proper gradients for the 6-inch and the 9-inch sewers and the depths of inverts of both sizes of sewers at the beginning and end of each. 8. Show by sketches how you would exclude sub-soil water from an under-ground cellar or godown. 9. How should sub-soil drains be laid and what is the object of laying this type of drain? 10. How would you dispose of the sewage of an isolated street, 500 feet in length so that the effluent might pass into a small river, adjoining the street, without causing a nuisance?

Government Technical Examinations: June 1912.

Time: Three hours: One question in each section

at least to be answered. I. General: 1. The main street of a town, three miles long, has the following falls at every change of inclination: A fall of 2 feet in the first half mile. A fall of 3 feet in the second half mile. A fall of 4 feet in the next mile. A fall of 6 feet in the last mile. What are the various gradients of the street? 2. The section of a cutting for a roadway 20 feet wide, side slopes 1 to 1 is as in fig. 7, plate 222. Estimate the quantity of earth to be excavated. II. Buildings: 3. How would you select a site for a residence? 4. What are the qualities of a good brick for sanitary works? What are the dimensions of a standard brick, and those of a Madras country brick? 5. What allowance per cubic space would you make per adult for (1) a residence, (2) a hospital? III. Water supply: 6. Give a dimensioned sketch you would recommend for (1) a draw-well, 10 feet diameter and 30 feet deep, (2) for a similar well provided with a pump and iron tank. 7. What is the chemical standard for a good drinking-water? 8. What is the practical limiting height of the suction pipe of a pump? IV. Drainage: 9. Up to what limit of size of sewer would you use glazed stoneware pipes? 10. Give a general specification for a 6″ glazed stoneware pipe sewer, including instructions for laying, jointing and testing the same. 11. What do you understand by self-cleansing velocity in a sewer? What velocity would you consider necessary for a 9″ pipe sewer running half full? What approximate gradient will give this velocity? V. General sanitation: 12. How would you dispose of the night-soil of a small town? Give full details, there being no system of drainage, or piped water supply. 13. How would you dispose of the refuse and sweepings of a town? Describe the process in detail from collection to final disposal.

The Medical College, Madras: June 1912.

Time: Three hours: 1. Give the recipe and specification for superior whitewash. 2. Draw a section, scale 1″ = 10″, of an open masonry drain with top width of 12″, as you would recommend for a sullage drain and discuss fully the merits of the section of drain you propose. 3. What do you consider are (*a*) the essential points of healthy construction in dwellings, and (*b*) the principal sources of unhealthiness in dwellings? 4. State how you would examine a well as to its suitability for a drinking water supply both as regards quantity and quality. 5. What are the different methods of purification of water for a town water supply? Discuss briefly the merits and demerits of (1) Sand filters, (2) Jewell filters, (3) Bell filters, and (4) Candy filters. 6. What will be the discharge in gallons per minute when flowing full of (*a*) a masonry conduit, 2′ inside diameter laid with a fall of 1/1320, (*b*) a cast iron pipe 6″ inside diameter with a gradient of 1/660, and (*c*) a stoneware pipe sewer 12″ in diameter laid with a slope of 1/264.? 7. What do you understand by a "self-cleansing velocity"? For sewers 4″ 6″, and 9″ what is the minimum velocity you would provide and what is the grade required to obtain it in each case? 8. Explain the rationale of biological purification of sewage. 9. What are the conditions generally aimed at in the final effluent of sewage after treatment as compared with crude sewage? 10. Describe the disposal works you would propose as component parts of an open drainage scheme for an Indian village provided with a protected water supply.

Government Technical Examinations: June 1913.

Time: Three hours: Only eight questions should be answered of which one at least must be from each section. I. General: 1. What is the usual size of drawing paper that you would adopt for drawing plans, and what is the smallest dimension of detail that can be shown on a plan the scale of which is 1/300? 2. What are level sections and what do you understand by the term "Natural Scale" when applied to such sections? In what circumstances would a natural scale not be adopted? 3. Estimate the quantity of earth that will require to be excavated from a trench to be dug for laying a 6-inch sewer in a level road 600 feet long when the depth of the trench at the upper end is 3 feet and the gradient of the sewer is 1 in 90. II. Buildings: 4. What is the object of a damp proof course in a building? In what circumstances is it required and in such cases what bad effects result from its omission? 5. Write down a specification for surkhi mortar and for surkhi concrete. 6. What is a couple roof? For what spans is it suitable and what difference is made in its construction when it is used for larger spans? III. Water Supply: 7. A deep well, 60 feet deep and 12 feet in diameter contains 6 feet of water in summer and 21 feet in the monsoon season and is provided with pulley and bucket arrangement. Show by a dimensioned sketch drawn to a suitable scale how such a well could be provided with a pump and a reservoir with taps from which the people could draw water instead of using their own ropes and buckets as at present. 8. What is the advantage of the arrangement you propose and what objections can be raised to its adoption? 9. The analysis of the water in an old well shows that during the monsoon the water is contaminated whereas during the summer season the quality of the water was reported to be fairly good. What precautions are taken to avoid as much as possible the deterioration of the quality of the water in a well during the monsoon months and at other times and in what respects do old wells require constructional improvement in order to render them sanitarily efficient? IV. Drainage; 10. A

6-inch pipe sewer is required in a branch street. State what items should be included in the estimate for this pipe sewer and briefly state the necessity for the items provided. 11. What happens when (1) a pipe sewer and (2) an open drain are constructed with insufficient fall and what means can be taken to obtain from such faulty construction as good working conditions as circumstances permit? V. Disposal of sewage: 12. The sullage discharged from a large open village drain stagnates in a pool at the outfall of the drain adjoining paddy fields the soil of which is stiff loam. How could the sullage be disposed of, in a sanitary manner, so as to stop the nuisance caused by the stagnation at present and what measure would you recommend within the financial resources of the District Board? 13. An isolated house of some importance in a village is unprovided with drainage arrangements beyond the pial of the house. Describe how sanitary arrangements for disposal of sullage could be made and the precautions necessary when executing such arrangements.

The Medical College, Madras: June 1913.

Time: Three hours: 1. Draw to a scale of 1 inch equals 4 feet the plan and section of a well fulfilling the following conditions: Subsoil: sandy. Summer water level: · 9 feet below ground. Diameter of well: 8 feet. Thickness of steining: 18 inches. Platform, gravel and clay backing, collecting drain and leading off drain, depth of well, etc., should be suitable. Parapet: 7 feet above ground. Pumps: two 1″ semi-rotary pumps should be fixed. II. What rules would you recommend to maintain a well in proper working order and condition? III. Write out a specification for whitewashing old walls of residential quarters in a general hospital. IV. What sanitary conditions would you have in view in selecting a suitable site for a new colony? V. In a town with a population of 25,000, there are three sites proposed for a night-soil depot the particulars of which are as follow: Site 1: Soil: black cotton. Area available: 310 acres. Direction south-east of town. Site 2: Soil: pure sand. Area available: 212 acres. Direction: north of town. Site 3: Soil: sandy loam. Area available: 196 acres. Direction: north-west of town. (*a*) Which of the three sites would you recommend and why? (*b*) Illustrate by a dimensioned sketch the locations of the trenches, roads, etc., in the site you recommend. VI. Arkonam in the North Arcot district had a population of 2,427 as per 1871 census, 3,220 as per 1881 census, 4,236 as per 1,891 census, 5,313 as per 1901 census, 6,896 as per 1911 census. (*a*) What is the population you would adopt for a water supply scheme for Arkonam? (*b*) What is the rate of supply per head per day to satisfy minimum sanitary requirements you would adopt? (*c*) For the rate in (*b*) and population in (*a*) state the discharge in gallons per minute of the gravity supply main to a service reservoir of 8 hours' capacity and the discharge of the delivery pipe from the reservoir. (*d*) State the sanitary points to which your attention would be directed if the proposed supply is from an infiltration gallery constructed in the bed of a river. VII. What points would you bear in mind in selecting a site for a village well? VIII. Describe the different systems of drainage usually adopted in this Presidency. Discuss the merits and demerits of each system. IX. State the essential principles on which the sizes of sewers in a closed sewerage scheme are usually determined? X. What are the objects aimed at in any treatment of sewage at disposal works? What are the requirements of the London Local Board in the matter of the disposal of sewage?

Government Technical Examinations: June 1914.

Time: Three hours: Eight questions to be attempted. 1. A well is 8 feet in diameter and 22 feet deep from ground level and the steining is $1\frac{1}{2}$ bricks thick; what is the quantity of brickwork in the steining? 2. The ground level of a street at its upper end is 269·20 and at its lower end 261·35 and the length of the street is 785 feet; it is proposed to lay a pipe sewer in this street, the size of the pipe sewer being 6 inches for the first 300 feet and for the remaining length of the street the pipe sewer will be 9 inches in diameter. What will be the depth below ground of the invert of the 9 inch sewer at its end assuming that the depth of the 6 inch pipe sewer invert at the beginning is 3 feet, the gradient of the 6 inch sewer is 1 in 100 and of the 9 inch sewer 1 in 190. 3. Specify three sources from which lime is manufactured in the Madras Presidency and the manner in which it is used. 4. Give the market forms of materials for lead paints and how the paint is prepared for use from these materials. 5. Show by neat sketches the outline of the different kinds of frame roofs and shortly describe a terrace roof. 6. Draw the cross section of a sand filter and explain how such a filter is worked. 7. Describe shortly the kinds of pumps you are acquainted with, their advantages and disadvantages and the circumstances in which they are most useful. 8. What is the object of a well platform, a collecting drain and what is termed a leading off drain and state their usual dimensions? 9. State how village tanks can be conserved. Illustrate your reply by sketches and give your opinions of how villagers could damage the means taken for conservation of the tanks and the obvious remedy to prevent such damage? 10. What are the

advantages of pipe sewers over open drains? Are there any disadvantages? If so, mention them. 11. What is the best method of disposing of the sullage of a large village which is provided with several important open drains which all converge to a single out-fall? Mention the requirements of the method you consider best.

The Medical College, Madras: August 1914.

Time: Three hours: I. Draw the cross section and plan of a cesspool, suitable for a small dispensary to a scale of one inch to one foot. Estimate the quantities of work for the cesspool as drawn by you. II. State (*a*) the rationale of the system of disposal of excreta on trenching grounds, (*b*) the conditions favourable for trenching and (*c*) the soils suitable for trenching. III. What points would you bear in mind when selecting a site for a new general hospital for a town of 20,000 people? IV. The census population of Srungavarappukota in the Vizagapatam district was as follows:

Census	Population.
1871	.. 5,078
1881	.. 5,329
1891	.. 5,715
1901	.. 5,862
1911	.. 6,385

In the Srungavarappukota taluk the percentage of increase of population was as follows:

	Per cent.
Between 1901 to 1911	... 3·5
Between 1891 to 1901	... 6·5

If you are now proposing a piped water supply for this village state (*a*) the population for which the scheme should be designed, (*b*) the quantity of water per head per day as a minimum requirement, (*c*) the average and maximum rate of supply per minute for the quantity in (*b*) above and for the population in (*a*) above. V. What are the present standards (chemical) of purity for (*a*) potable water and (*b*) sewage effluents? VI. State the simple and ready tests for rough analysis in testing water for sewage and lead. VII. State the present-day rules of practice in the matter of "house drainage," illustrating your answer with sketches. What is the London Local Government Board regulation regarding intercepting traps near the sewers? How is it proposed to be amended and why? VIII. What are the two principal systems of sewerage? Discuss the merits and demerits of the two systems.

Government Technical Examinations: December 1914.

Time: Three hours: Seven questions may be attempted. 1. Draw a scale 6 inches long of which the representative fraction is $\frac{1}{500}$. 2. A 6-inch branch sewer 300 feet long, grade 1/100 joins a 12-inch main sewer, grade 1/295. What is the invert level of the 12-inch sewer at a distance of 500 feet below the junction if the reduced level of invert of 6-inch sewer at its beginning is 100·00? 3. What is the possible influence of the weather on the various building materials in the Madras Presidency and what protective remedies are adopted? 4. What is the area and cubic space required for an ordinary ward of 12 beds and what height of ward is usually taken in calculating the cubic capacity? How is ventilation ensured in the ward? 5. Draw to a suitable scale on your answer paper a cross section and a plan showing one seat of a sanitary latrine suitable for a mufassal town and briefly state the essential requirements for its upkeep. 6. A well is 8 feet in diameter and contains 10 feet of water when unused. It is bailed out completely in the dry weather by 9 A.M., and after bailing is stopped the rise of water level is observed as follows:

		12 NOON	... 2·50
9 A.M.	... 0	12-30 P.M.	... 2·75
9-30 A.M.	... ·50	1 P.M.	... 3·00
10 A.M.	... 1·00	1-30 P.M.	... 3·10
10-30 A.M.	... 1·50	2 P.M.	... 3·15
11 A.M.	... 2·00	9 A.M.	... 4·00
11-30 A.M.	... 2·25	9 A.M. Following day	... 4·50

What quantity of water daily would you consider as the approximately safe yield from this well? 7. What is the discharging capacity of an open drain of rectangular section 2′ × 2′ when flowing full, gradient 1 in 528? 8. Show by a neat sketch a syphon trap and give briefly reasons for its use. 9. What is generally the best method of disposal of sewage in the Madras Presidency and why? Give a cross sectional sketch of a sub-soil drain and state when and under what conditions it is required.

The Medical College, Madras: August 1915.

Time: Three hours: I. What are the objects aimed at in any treatment of sewage? II. State the relative merits of còntact beds and percolating beds. III. For a hospital water supply how many coolies will you employ for working a kite motion pump when (1) the daily working hours are 8, (2) the daily supply required is 28,800 gallons and (3) the total lift is 27·5 feet? IV. What important points will you bear in mind: (*a*) in selecting sites for wells, (*b*) in selecting sites for a new colony to accommodate 1,000 people, (*c*) in selecting sites for the construction of new dispensaries? V. For an Indian town of 20,000 people what quantity of water per head per day will be considered as a reasonable provision? Give full details for the rate of provision you recommend. VI. Discuss the merits and demerits of the different patterns of

damp proof courses. VII. What are the constituent parts of a town in town-planning? VIII. In town-planning what do you consider as "future evils" and what measures will you now adopt to prevent them?

Government Technical Examinations: December 1915.

Time: Three hours: Not more than seven questions should be attempted. Free use of sketches may be made to illustrate answers. Sketches need not be made to scale; dimensions should be marked in figures; 1. Describe the principle of overhead ventilation of rooms as applicable to this country, and state the conditions under which such ventilation is necessary. Sketch and describe the method of overhead ventilation in (*a*) a tiled roof with coupled rafters, (*b*) a terraced roof. 2. Sketch the ground plan of a dispensary suitable for a small town or village. Describe the use of the various rooms. Describe the water supply arrangement suitable for a dispensary of the kind sketched, the source of supply being a well in the compound of the dispensary. 3. What are the factors which determine the size of a surface drain? A surface drain is required to serve an area of one-twentieth of a square mile. (*a*) Calculate the quantity of water the drain will have to carry per second under rainfall conditions prevailing on the East Coast; (*b*) Find the velocity in a semi-circular drain 3 feet wide when discharging the quantity of water as calculated above. 4. Draw to a scale of one foot to an inch a cross section of a Cuddapah slab drain with right-angled bottom having a top width of 2 feet, showing the thickness of slabs, concrete foundations and cement jointing. 5. Make an estimate of: (*a*) quantities, (*b*) cost of a drain 300 feet long, as drawn in answer to question 4, at Madras rates. Write a short specification for the work. 6. Sketch the ground plan and cross section of a block of two huts suitable for scavengers. Describe how the floor should be constructed, and give your reasons for the flooring you recommend. 7. Describe a tube well and the method of sinking it. State the conditions of sub-soil and sub-soil water in which a tube well is useful. State the advantages and disadvantages of a tube well as compared with an open well. 8. Describe fully the method of laying out a sewage farm, 400 feet square. The land slopes towards a ditch on one side. 9. What is the object of a platform round a well. State arguments for and against covering a well in daily use. A well in gravelly soil is 30 feet deep and it is considered necessary to exclude sub-soil water from the top 15 feet of the soil. Describe the method of achieving this object.

APPENDIX A.

RULES FOR WORKING SAND FILTER BEDS AS ISSUED BY THE SANITARY ENGINEER, MADRAS.

Sand For Filters.

1. The sand used should neither be very fine nor very coarse. Its uniformity co-efficient should be somewhere between 2 and 3. The sample proposed for use should first be sent to the Sanitary Engineer to Government for examination and advice as to what treatment it should receive before using. If it is found necessary to screen the sand the Council may request the Sanitary Engineer to indent for such screens as he may decide are necessary for the purpose.

2. As a rule the topmost layer of sand should pass through screens of 10 meshes but be retained on 40 meshes to 1 inch lineal, and the sand in layer below same is that retained in screens 10 meshes to 1 inch lineal.

New Filters: Filling With Water.

3. After completion of the filters the unfiltered water should be run slowly on to the surface of sand, through the copper wire gauze inlet screen, so as to fill up the filter bed with water.

4. The rate of filling should not exceed 4 inches per hour and care should be taken to avoid scouring the surface of the sand by a rush of water from the inlet chamber, *e.g.*, if the total depth of the filter bed from bottom to top of water level is 8 feet, it should take 24 hours to fill the bed.

5. If the water is observed to be rushing too fast on to the sand surface, the inlet valve should be regulated so as to reduce the flow and scouring of sand thus prevented.

6. The filter bed should be filled with unfiltered water until there is 3 feet water above the surface of sand.

Time Of Rest.

7. This water should be allowed to stand quiescent in the filter bed for 24 hours or longer if the unfiltered water is clear. It may be taken as a guide that 24 hours is sufficient for discoloured or laterite water and 3 days for water not so discoloured.

8. At the end of these times a sufficient thickness ($\frac{1}{4}$ inch) of slimy layer will have been deposited on the surface of the sand.

Running Of Filtered Water To Waste On Starting.

9. The scour valve of the filter bed should then be slowly opened, so that the decrease of water level is not more than 4 inches per hour. The inlet valve should be kept open so as to keep up the water level as soon as a test has shown that the opening of the scour valve is capable of reducing the water level at the rate of 4 inches per hour.

10. The scour valve should be left open for 3 days and the water which is filtering through the filter bed should be run *to waste* during this time.

Starting Of Filter.

11. At the end of 3 days the scour valve may be shut and the filtered water outlet valve opened, so that the filtered water can be sent to the service reservoir for the use of the town.

Old Filters: Filtering Head.

12. In working filters it will be found that the difference of level between the unfiltered water standing on the filter bed and the filtered water in the filtered water-chamber gradually increases by, say, half an inch daily from one inch to the limit, which is 24 inches. This increase is due to the thickening of the slimy layer on the surface of the sand.

Limit Of Head.

13. As soon as this limit of 24 inches is reached, the filter bed inlet valve should be shut and the water level allowed to fall in the filter bed until the slimy layer is exposed.

Scouring Of Filter.

14. The outlet valve should then be shut and the scour valve opened and the filter bed emptied at the rate of 4 inches per hour.

Drying Of Bed By Exposure To Sun.

15. The filter bed should then be allowed to dry by exposure to the sun when it will be found that the slimy layer will dry in patches and these patches will curl up as they get drier.

Planks.

16. As soon as the surface of the bed is sufficiently dry, planks, at least 12 inches wide and $\frac{3}{4}$ inch thick should be laid on the surface of the sand so as to form pathways (as described later on) for coolies to stand on. (This work should be done only after attending to cleanliness of coolies and materials as described in paragraphs 18 and 19

below). The planks should be laid in lines 12 feet apart centre to centre right across the filter bed.

17. In placing these planks in position and in the subsequent scraping of the slimy layer and sand surface, on no account whatever should a coolie or other person be permitted to place a foot on the filter bed surface as such a proceeding will result in contamination of the filter bed.

Coolies To Wash.

18. Before the coolies are permitted to walk on the planks, they should wash themselves with filtered water and it will be the duty of the Superintendent of the water works to see that this requirement is rigidly observed.

Tools, Etc, To Be Washed.

19. The planks, rakes, mamooties, baskets, and ropes used in the operation of cleaning a filter bed must also be well washed with filtered water.

Pathways.

20. The first plank will be lowered into the filter bed by ropes and then a short ladder, which has been well washed in filtered water, will be placed on this plank, and will lean against the filter bed wall.

21. A coolie or two will then descend the ladder and will stand on the first plank and will receive other planks which will be placed in lines across the filter bed as already described.

Scraping Of Slimy Layer And Surface Sand.

22. As soon as the planks are laid in lines, coolies, armed with wooden rakes will first scrape off the slimy layer and remove it out of the filter bed, and then ½ inch to 1 inch of sand, as the Superintendent will decide after inspection, will be scraped into long rows alongside the planks.

Rakes.

23. The rakes will be made of wood and will consist of a handle, 6 feet long and 1 inch in diameter and a head made of plank, ½ inch thick, 4 inches wide and 18 inches long firmly fastened and strutted to the handle.

Removal Of Scrapings From Filter Bed.

24. As soon as all the spaces between the planks are scraped by the rakes, the scrapings should be filled into baskets, using mamooties, and removed away from the filter bed site either close to the sand washing box for rewashing or finally disposed off on some low ground.

Rewashing Of Sand.

25. In those cases where it is found cheaper to rewash the sand removed from filter beds instead of using fresh sand, the slimy layer having first of all been removed from the filter bed, the ½ inch to 1 inch of silted sand which was underneath the slimy layer should be removed to the sand washer to be washed and exposed to the sun until it is again required for use on the filter beds.

Exposure To Sun Of Scraped Bed.

26. The filter bed having been scraped as described should be exposed to the sun for 3 days or longer, if possible.

Starting Filters After Cleaning.

27. At the end of this time filtered water should be admitted to the bed *from bottom upwards* from one of the other filter beds until the water rises to 6 inches above the surface of sand. The rate of admission should be the same as the safe rate of filtration for the filter, *viz.*, 4 inches per hour as a rule. Then unfiltered water should be admitted through the ordinary inlet to the filter until the water rises to the full height in filter, when the inlet valve should be shut. The water should then be allowed to remain undisturbed for a period of 24 hours at the end of which period the scour valve should be slowly opened to let out all the water thus allowed to settle until the water level in the filter stands six inches over the sand layer. While the scour is kept open, care should be taken that the slimy layer formed on the top of sand layer is in no way disturbed. As this slimy layer is found to play an important part in the efficient working of sand filters, the process of admitting water into the filter, allowing it to settle itself quickly for 24 hours, then withdrawing by the scour valve without disturbing the slimy layer even very slightly, should be repeated as often as necessary until the slimy layer formed on top of the sand is about ¼″ thick. The filter is then ready for working for the town supply.

Periods Between The Scrapings.

28. A filter bed will require scraping at unequal periods of time depending on the turbidity of the unfiltered water and the time will be shown when the limit of 24 inches head already referred to is reached. Some filter beds using muddy water will require scraping after three weeks and others only after three months.

Removal And Washing Of Filtering Materials.

29. As soon as analysis shows the necessity for removing the sand, broken stone and drains of a filter bed for cleaning purposes, this should be done. As a rule, every filter should be cleaned at least once every two years or oftener, if found necessary. When a filter has been found to clog up fast, that is, when the interval between ordinary cleanings is

much less than usual, then the filter should be thoroughly overhauled and relaid. First the dirty water should be run out by the scour valve provided for the purpose. Then the sand should be carefully removed, as soon as it is dry and thoroughly washed in a sand box or other device preferably with water under pressure entering the sand box from the bottom. The sand thus cleaned should be carefully dried and screened with screens recommended by the Sanitary Engineer and stacked near the filter in different heaps according to their grade of coarseness. Any sample picked up at random from the heaps, when put into a tumbler of water, should impart no sign turbidity to the water.

30. Then the drainage layers should be dealt with as follows: Immediately the superimposed sand is removed, the drainage layers should be well soaked in water. While they are being thus soaked they should be turned over by a rake, shovel or other contrivance so as to facilitate the removal of deposits of any foreign matter with which they may have become coated. The drainage layer should then be well rinsed in clean water, dried and stacked in heaps according to sizes. Any sample picked up at random and thrown into a bucket of water should impart no sign of turbidity to the water.

31. The walls, floor and under-drains of the filter should then be carefully scrubbed, washed, lime-washed and exposed to the action of the sun for a couple of days and rewashed with clean water.

32. While the filter is thus being treated, advantage should be taken to examine and put right all the inlet, outlet, scour and overflow valves, screens and other appendages.

33. Then in relaying the filter, the drainage layer and sand shall be laid as in fig. 2, plate 222.

34. If the materials removed from the filter be found insufficient after washing, then new material should be procured and treated as if such material had been removed in the first instance from the filter in a dirty state.

35. The filter should then be re-started in strict accordance with instructions described under paragraph 27 above.

Rate Of Working.

36. The rate of working a filter-bed should not exceed four inches per hour or 450 gallons per square yard per day.

APPENDIX B.

NOTE ON THE QUANTITY OF WATER REQUIRED PER HEAD IN THE PUBLIC WATER SUPPLIES OF BENGAL AS ISSUED BY G. B. WILLIAMS, ESQ., M.I.C.E., M.I.M.E., SANITARY ENGINEER, BENGAL.

Introduction.

Considerable misapprehension appears to exist amongst members of Municipal Bodies and other persons in this country, concerned with Local Government, in regard to several important points connected with the public water supply of towns. Certain fallacies are current as to such matters as the quantity of water required per head, the number of house connections that can be permitted, and the advantages and disadvantages of separate unfiltered water supplies, which at times become obstacles in the way of the progress of much-needed schemes, and lead to mistaken policies being adopted in the management of water works after they are completed. Moreover, the serious effect of wasting water, both on the municipal finances and also on the efficiency of the supply is very little appreciated.

A statement of how much water is really required for various purposes in different classes of towns in Bengal may remove some of this misunderstanding. My object in this note is to supply this information and at the same time to explain briefly some of the principles on which water works in this country should be designed and managed so as to give an adequate supply without encouraging wasteful and unnecessary extravagance.

Although the note is primarily intended for Bengal, my remarks to some extent apply to towns in other parts of India and the East.

Waste Of Water.

2. The first point to be constantly borne in mind is that in Bengal the economic factor in the problem of water supply is the all-important one. In all public water supplies there is a certain amount of waste. In some European and American towns it is prodigious. As the capital cost and working expenses of water works are approximately in proportion to the daily quantity of water supplied, a community which is wasting 50 or 75 per cent. of its water supply is paying two or three times as much for the water required as it need do.

Waste of water is an expensive luxury at any time, but in the wealthy towns of Europe and America the rate-payers are able to pay for many municipal luxuries that cannot be afforded in India. In Bengal, municipal water supplies on the lines of those in European and American cities are, in most cases, absolutely out of the question, and the waste of water is a proportionately more serious matter. There are two ways of paying for water consumed (*a*) by a water-rate levied on the rate-payers in the area supplied, and (*b*) by water sold by meter. In Bengal the income from (*a*) is limited by law, and in most of the provincial towns the number of consumers who would be prepared to pay for any large quantity of water sold in bulk is very small. Even with generous assistance from Government, it is only just possible for a certain number of the provincial municipalities to finance a limited public water supply, and the ability to keep down the consumption to a reasonably low figure may make the whole difference between a supply of good water sufficient for the ordinary necessities of life and none at all. The all-important question in any town is therefore: What is the minimum supply that will satisfy the legitimate demands of the inhabitants.

Domestic Consumption.

3. The quantity of water actually required for purely domestic consumption, that is, for drinking, cooking, washing utensils, etc., is small. There are towns in Bengal, supplied entirely from street standposts, which do not use more than 2 gallons per head. In Gaya, where for many months a constant supply was given under a high pressure through street standposts to the whole town, containing some 80,000 inhabitants, the average daily consumption, including leakage from mains and standposts, did not exceed 5 gallons per head of the population served.

In comparing this quantity with the consumption in other countries, it must be noted that in Bengal the lower class people do not generally use filtered water for bathing in. They bathe either in tanks or in the rivers. In almost every town there are numerous places where this can be done.

Quantity Per Head Is Proportional To Population.

4. Roughly speaking it may be said that in this country it is generally (although by no means

invariably) the case, that within certain limits, the larger the town is, the more is the *per capita* consumption of water. In a big town there is usually a larger proportion of better-class inhabitants living in good-sized houses who require house connections, and are able to pay for them, than in a small one. Small towns have no sewers and frequently few masonry drains; so little water is required for flushing. Some of the larger towns in Bengal will probably have sewerage systems within the next few years, and this will mean a supply of water for connected latrines, urinals, etc. These are some of the causes which affect the tendency of the consumption of water per head to increase with the size of the town. The relationship between numbers of population and rates of consumption, although subject to many exceptions, is sufficiently general to make it possible to roughly classify the requirements of the towns in accordance with population.

5. For this purpose I divide the Bengal towns into five categories as follows:

Class A: Towns containing less than 10,000 inhabitants.

Class B: Towns containing from 10,000 to 25,000 inhabitants.

Class C: Towns containing from 25,000 to 50,000 inhabitants.

Class D: Towns containing from 50,000 to 100,000 inhabitants.

Class E: Towns containing from 100,000 to 200,000 inhabitants.

There are no towns with over 200,000 inhabitants in Bengal, except Calcutta, in which the conditions differ materially from those in the other towns in the Presidency, and in any case a town of 400,000 or 500,000 inhabitants would probably not require much more water (if any) per head than one of 200,000.

Quantity Per Head For Towns Containing Less Than 10,000 Inhabitants.

6. Taking these classes in order, in towns of class A, the utmost supply that can usually be afforded is one entirely through street standposts. No water is used for public purposes at all, and for private consumption from 2 to 5 gallons per head per day is sufficient, including leakage from standposts and mains.

Quantity Per Head For Towns Containing From 10,000 To 25,000 Inhabitants.

7. In towns of class B there are likely to be a certain number of better class persons living in fair-sized houses. These will naturally wish to have private house connections. The vexed question of house connections is thus introduced. It may be said at once that private connections, where they can be afforded, are from a sanitary point of view desirable. They encourage personal cleanliness and make it less probable that polluted water will be used for drinking or washing utensils. This is, however, only within certain limits. The conditions of life in Indian towns must be entirely revolutionised before it will be possible to give every house a separate connection, as is done in an English town. Private connections to the *bustee* huts, hovels, and low class *pucca* houses, which form the majority of dwellings in these towns, would be entirely out of place, and the inhabitants of this class of houses must in the future, as in the past, continue to draw their water from the public standposts.

Apart from this, however, the chief reason for limiting the private house connections is the very great increase in the consumption that results from their introduction. Some extra consumption is natural and legitimate. Persons supplied through house connections use the water supplied for bathing, for flushing down house drains and for other purposes, for which the population served by the street standposts generally do not require it. On the other hand, much of the water, drawn through the private house connections, is absolutely wasted. Taps are left running all day long, baths and vessels are filled at night and then emptied without being used in the morning, and the supply is abused in every possible way. Experience has shown in Bengal that persons supplied through an unmetered private house connection may in some cases each use as much as 20 times the quantity used by those who get their supply from street standposts. I have no hesitation whatever in saying that unmetered house connections are luxuries that no Bengal town can afford and which should never be permitted.

Provided there is no serious waste, 20 to 25 gallons per day is quite sufficient for any person supplied through a house connection where there are no connected water-closets, or dumping sinks, and 25 to 30 gallons where there are. By metering the connections and charging for excess water consumed, there will be no difficulty in keeping down the consumption to these average figures.

8. In a town of the class I am now considering, another question also arises, and that is, the quantity of water used for public purposes. A town of class B is unlikely to have a sewerage system, no water would therefore be used for connected latrines, night-soil dilution or sewer-flushing. Water is, however, required for drain flushing and road watering and for the supply of public buildings.

Road watering is a very useful sanitary measure. The dust which is blown about Indian towns in enormous quantities during the dry weather has an injurious effect on the respiratory organs, and moreover it is liable to carry polluting matter into

food. The quantity of water required for road watering is not really large. It varies in different towns according to the length of roads to be watered, their average width and the material of which they are made. It is obvious, for example, that Calcutta, with its many wide roads, will require more water per head of population than Howrah. If the road watering is confined to the main streets where it is most required, 1 gallon per head per day is generally sufficient for watering once a day and 2 gallons per head for two daily waterings in a small or medium-sized town. For larger towns these figures become $1\frac{1}{2}$ and 3 gallons per head per day, respectively.

Drain flushing also requires but little water if proper flushing tanks are used. The quantity required may sometimes be further reduced by feeding the flushing tanks from the waste from the street standposts. The quantity required for drain flushing should not exceed $\frac{1}{4}$ gallon per head of population per day.

Supply of public buildings may be taken at an average of another $\frac{1}{4}$ gallon per head per day. In many places it is much less.

The only other items of consumption in the class of towns I am considering are: the leakage from mains and standposts, and water used for sand washing in the case of a slow sand filter installation, and filter washing with mechanical filters. The leakage from the mains and standposts depends on how they have been laid and are being looked after. It should, in water works of this size, not exceed $\frac{1}{2}$ gallon per head per day. Sand washing and filter washing will require about $\frac{1}{2}$ gallon per head per day.

9. To illustrate the foregoing remarks, I will take an imaginary town of 20,000 inhabitants. Probably one-tenth of the population will be supplied through private house connections, and on the foregoing premises the total daily consumption of the town will be:

	Gallons.
2,000 persons supplied through private house connections with 20 gallons per head per day ...	40,000
18,000 persons supplied through street standposts with 5 gallons per head per day	90,000
Street watering (once a day)	20,000
Drain flushing ...	5,000
Supply of public buildings.	5,000
Leakage	10,000
Filter or sand washing ...	10,000
Total ...	180,000 or 9 gallons per head.

10. Here I may refer to the idea generally prevalent that a considerable saving can be effected by using unfiltered water for such purposes as drain and sewer flushing, latrines and road watering. This notion is a fallacy. It is possible that in certain circumstances in a large town, the saving in the cost of filtration and pumping might financially justify the extra cost of a double set of mains and pumping stations, but in the ordinary Bengal town this would certainly not be the case, and in any circumstances the objection to an unfiltered water supply from a sanitary point of view and the troubles that accompany its use, make it undesirable even if it were not (as it would be) in such cases an additional expense. Calcutta is one of the few towns in the world which possess an unfiltered water supply. So far as I know, it is unique in having separate house connections for unfiltered water.

It may, I think be safely assumed that no other Bengal towns will follow Calcutta's example and introduce a complete unfiltered water supply system, so that any water required for public purposes will come from the filtered water supply.

Quantity Per Head For Towns Containing From 25,000 to 50,000 Inhabitants.

11. I next come to the towns in class C, which are those having between 25,000 and 50,000 inhabitants. This class will differ from class B mainly in having a larger number of persons supplied through private house connections. Otherwise the proportions will be much the same as in the latter.

As an example, I will take a town of 40,000 inhabitants and assume that of these one-sixth, or say 6,500 persons, are supplied through private connections.

The daily quantities required will be:

	Gallons.
6,500 persons supplied through private connections with 20 gallons per head per day	130,000
33,500 supplied through street standposts with 5 gallons per head per day	167,500
Road watering (once a day)...	40,000
Drain flushing	10,000
Supply of public buildings ...	10,000
Leakage	20,000
Sand or filter washing ...	20,000
Total ...	397,500, or say 10 gallons per head.

Quantity Per Head For Towns Containing From 50,000 to 100,000 Inhabitants.

12. In class D towns, containing a population of from 50,000 to 100,000 persons, there should

be in the near future a partial system of sewers, public connected latrines and dumping depots. There may also be possible a few private water-closets, and I allow in consequence a somewhat higher consumption per head for the private house connections. The quantity of water required for public latrines and night-oil dilution will be about 3 gallons per head of the total population and for sewer flushing $\frac{1}{5}$ gallon per head.

In the case of a town of 100,000 inhabitants the road watering may take place twice a day and I allow $2\frac{1}{2}$ gallons per head for it. This may include a certain quantity of water required for public gardens.

For a town of 100,000 inhabitants I consider the following would be a fair daily supply. One-fifth of the inhabitants are assumed to be supplied through private connections:

	Gallons.
20,000 persons supplied through private connections with 25 gallons per head per day ...	500,000
80,000 persons supplied through street standposts with 5 gallons per head per day	400,000
Road watering (twice a day)	250,000
Drain flushing ...	25,000
Sewer flushing ...	20,000
Public latrines, urinals and night-soil dilution ...	300,000
Supply of public buildings, etc.	25,000
Leakage, etc., say ...	75,000
Sand and filter washing ...	75,000
Sundry	30,000
Total ...	1,700,000 or 17 gallons per head.

Quantity Per Head For Towns Containing From 100,000 To 200,000 Inhabitants.

13. In the last class of towns, class E, those having populations of between 100,000 and 200,000 inhabitants, the sewerage system should be more fully developed. The quantity of water required for public water-closets, latrines, urinals and night-soil depots will probably be about $3\frac{1}{2}$ gallons per head. One-fourth of the population may be supplied through house connections, and I allow them a quantity of 30 gallons per head per day to provide for the increased number of water-closets and private dumping sinks.

In a town of 200,000 inhabitants the total supply given should be as follows:

	Gallons.
50,000 persons supplied through private connections with 30 gallons per head per day ...	1,500,000
150,000 persons supplied through street standposts with 5 gallons per head per day	750,000
Street watering (twice a day)	600,000
Drain and sewer flushing...	90,000
Public latrines, urinals and night-soil depôts ...	700,000
Supply of public buildings, etc.	50,000
Leakage, etc.	200,000
Filter or sand washing ...	200,000
Sundry	110,000
Total	4,200,000 or 21 gallons per head.

Summary Of Estimates For Quantity Per Head.

14. The following table gives the summary of my estimates of the quantity of water required *per capita* under the different headings for the various classes of towns:

Consumption in gallons per head per day.

	Class A.	Class B.	Class C.	Class D.	Class E.
Domestic consumption (including private water-closets).	5	6·5	7·43	9·00	11·25
Public latrines and urinals, night-soil depots, etc.	...	...	...	3·00	3·50
Supply of public buildings.	...	·25	·25	·25	·25
Sewer and drain flushing.	...	·25	·25	·45	·45
Street watering ...	...	1·00	1·00	2·50	3·00
Leakage from mains, street standposts, etc.	...	·50	·50	·75	1·00
Filter or sand washing.	...	·50	·50	·75	1·00
Sundry (stables, cow-houses, dhobikhanas, etc.).	...	...	·07	·30	·55
Total ...	5	9·00	10·00	17·00	21·00

It is to be understood that although the towns are classified in accordance with their population there are several towns which, owing to local circumstances, must be treated as being out of their proper class. For example Darjeeling, although according to its population it should be in class B, may be considered a class D town, whilst Howrah with its

nadequate drainage system and with no form of sewerage at all is at present a class C town. Dacca is now a class C town, but when the new sewerage system is in complete operation, it will become a class E town.

15. The figures in the above table are for a constant supply throughout the 24 hours and give, in my opinion, the maximum quantities required for domestic and public purposes in the towns of the various classes. They are the hot weather figures. In the rains and cold weather the consumption should be less.

They do not include any water supplied for trade purposes. There are certain cases in which it might pay a town to supply water for trade purposes, such as for railway locomotives or for boilers at manufactories, or to a distillery; but as it is impossible to generalize about circumstances which might make such a policy advisable, it is useless to discuss them in this note.

Conclusion.

16. To sum up, the following principles should govern the introduction and management of water supply schemes in Bengal:

(1) The water supply of a Bengal town is largely an economical problem, and no town in this Presidency, outside Calcutta, can afford an extravagant supply on the lines of some of the European and American towns.

(2) Such large supplies are in fact not required. The legitimate demands of mufassal towns are met by water supplies varying from 4 or 5 gallons per head in the case of a small town up to a little over 20 gallons per head in the case of a town of 200,000 inhabitants.

(3) This includes in the case of the larger towns water required for public purposes, such as road watering, drain and sewer flushing, and, where they exist, latrines, water-closets, urinals and night-soil depôts.

(4) Separate unfiltered water supplies are neither necessary nor desirable, and in the case of most towns would be more expensive than using filtered water for public purposes.

(5) The possibility of being able to give and maintain a sufficient and proper supply depends mainly upon the prevention of waste in private house connections. Unrestricted and unmetered house connections will ruin any water supply.

(6) House connections must be limited in number to those that the municipality can afford to give. Every private connection must be metered and excess consumption charged for at a sufficient rate to make real waste of water an expensive luxury. The number of persons supplied by such house connections would probably vary from about one-tenth of the population in a small town up to possibly one-fourth of the population in a town of 200,000 inhabitants.

(7) The private house connections must not be given in such numbers or under such conditions as will allow them to interfere with the water required by the street standpost consumers or for public purposes. It is more important to water roads and flush drains than to give a large number of house connections.

(8) Provided, however, the rest of the community do not suffer therefrom, the grant of private house connections to better class houses is in itself desirable.

(9) With due care in the management of the water supply even a moderate-sized town can usually provide enough water for maintaining the sewers clean in a partial sewerage system. Such a system will probably enable a saving to be made in the conservancy considerably greater than the cost of the extra water so used.

17. Finally, I may say that if in any town in this Presidency the consumption per head is much in excess of the quantity which, having regard to its population and the local condition, would suffice for its needs according to the table I have given in this note, it may be assumed that there is waste somewhere, and the municipal authority should carefully enquire into the matter. The ordinary municipal rate-payer has no idea of the amount of money which a serious waste of water is costing him. In a municipality in which it cost 3 annas to supply 1,000 gallons of water (an ordinary figure), the waste of 100,000 gallons a day means a waste of nearly Rs. 7,000 per annum, and there are few municipalities which can afford to throw away this amount with absolutely nothing to show for it.

APPENDIX C.

PRELIMINARY PARTICULARS FOR IMPROVEMENTS TO EXISTING WELLS AND FOR NEW WELLS.

I.—Improvements To Existing Wells.

1. The subordinate who should draw up plans and estimates for improvements to existing wells should first be provided with instruments and stationery of the following description:

(1) A measuring tape 100′ long.
(2) A third-class mathematical instrument box.
(3) Two set squares, 60° and 45°.
(4) One 33′ scale with offsets.
(5) One foot rule.
(6) One drawing board with T square.
(7) One Indian ink cake.
(8) One crimson lake cake.
(9) One Prussian blue cake.
(10) Two sable hair brushes.
(11) Two slabs.
(12) Twelve yards of tracing cloth.
(13) Writing materials, estimate forms, etc.

2. Every proposal for improvements to an existing well should be accompanied by plans, estimates, and report of the following description:

(1) Site plan showing the well proposed to be improved, the wells near it within a radius of 1,000 feet, and the position of houses, roads, markets, slaughter-houses, latrines, tanks and rivers within that range.

(2) An enlarged plan of well showing the existing works in black and the proposed improvements in red. The improvements proposed should as far as possible be of a nature to ensure that after these improvements are carried out the improved wells approach the condition of those shown on the Sanitary Board type designs.

(3) Estimate in the prescribed form.

(4) Report containing the following particulars.

(i) Description of the condition of the well proposed to be improved with reference to (*a*) diameter, (*b*) thickness of steining, (*c*) whether the steining is of brick in mud or chunam mortar, (*d*) lowest summer water level, (*e*) maximum water level, (*f*) bottom of well and (*g*) the improvements now proposed.

(ii) whether the water in the well is reported to be good in quality and whether the field tests as specified in a subsequent paragraph have been carried out, and the results of such field tests.

(iii) The soil into which the existing wells are reported to have been sunk and the general character of the surface and underlying soils as far as can be gathered from reliable reports or observations.

3. Field tests to ascertain whether the water in a particular well is not brackish: The subordinate should be given a small teakwood box containing; (1) one 4 oz. glass-stoppered coloured bottle containing a solution of silver nitrate made by dissolving in the proportion of 22·5 grains of pure silver nitrate in one ounce of distilled water; (2) one 4 oz. glass-stoppered bottle containing a solution of yellow potassium chromate made by dissolving in the proportion of 45 grains of yellow chromate in one ounce of distilled water; (3) one 4 oz. glass-stoppered spare bottle; (4) one ounce measure; (5) one minim measure; (6) four glass test tubes; and (7) three pipettes.

4. The tests that the subordinate should carry out consist of his using one-quarter ounce of sample water and adding to it two drops of chromate solution from a pipette to give the sample a yellow colour. He should then add carefully by means of a clean pipette drops of the silver nitrate solution till the sample turns red and compare with the number of drops required in a known potable water. From experience the following are rough standards:

First quality potable water.	1 drop
Fair quality ...	. 2 to 3 drops.
Indifferent quality	. 4 to 5 drops.
Brackish	. above 5 drops.

II.—New Wells.

5. The selection of a suitable site for a new well will depend on a number of considerations for which no hard and fast rules can be given, such as the positions of existing wells in good or ruined condition indicating possibilities of constructing a new well at a particular site in their vicinity, the results of boring operations, etc. Wherever possible new wells should invariably be constructed at sites where, by means of shallow borings put down, the results of water levels, sub-soils and potability of water have been ascertained.

6. If local conditions warrant the reasonable inference that a new well in a particular site is likely to yield a supply of water good in quality and sufficient in quantity, then proposals based on type designs may be drawn up and submitted for sanction in the usual course, accompanied by plans,

estimates, report and particulars of the undermentioned description;

(1) Site plan showing the proposed location of the new well, positions of existing wells within a radius of 1,000 feet, positions (within the same range) of houses, roads, markets, slaughter-houses, latrines, tanks and rivers.

(2) A statement of the number of the type design proposed to be adopted and an enlarged plan of well showing the assumed maximum and summer water levels and the surface and sub-soils.

(3) Estimate in the prescribed form.

(4) Report containing the following particulars:

(i) Description of the different works comprising the new well with reference to (*a*) diameter, (*b*) thickness of steining, (*c*) whether the proposed steining is of brick or stone, (*d*) the assumed summer and maximum water levels, (*e*) proposed bottom of well.

(ii) The local conditions which go to determine an inference as to the water in the new well being good in quality and sufficient in quantity.

(iii) The soil into which the existing wells near the proposed well are reported to have been sunk and the general character of the surface and underlying soils as far as can be gathered from reliable reports.

(iv) Whether the water in the existing wells near the proposed well-site is reported to be good in quality and whether the field tests specified in a previous paragraph have been carried out and the results of such field tests.

(v) The location of pumps proposed to be fitted, bearing in mind that the pump barrels should not be more than 20 feet above the foot valves of suction pipes.

APPENDIX D.

GENERAL INSTRUCTIONS FOR DRAWING UP PROPOSALS FOR DRAINAGE AND WATER SUPPLY FOR LARGE INSTITUTIONS AND BUILDINGS IN TOWNS POSSESSING CLOSED SEWERAGE SYSTEMS AND PIPED WATER SUPPLIES.

Report And Plans For Drainage Proposals.

(i) A report clearly describing the proposed works stating also how the existing methods, if any, are defective. The report should be a self-contained one avoiding reference to other papers and correspondence between various offices. This report should also contain information as to the quantity of sewage to be dealt with by the various branch sewers, and also (*a*) the resident population, of the building and (*b*) the non-resident population *i.e.*, those who attend during certain hours only.

(ii) A plan showing:

(*a*) the blocks of buildings to be drained;

(*b*) the surrounding Municipal streets, drains or sewers with their sizes and positions of manholes;

(*c*) the alignment of branch drains or sewers with their dimensions;

(*d*) the position of manholes, inspection chambers, syphons, silt traps, air inlets, ventilators, etc., on them;

(*e*) the direction of flow of sewage in the proposed branch and existing Municipal drains or sewers (to be shown by arrows);

(*f*) the ground level of principal points for guidance in considering the lie of the ground.

(iii) Plans of longitudinal sections of *all* the proposed branch drains or sewers, however short they may be, showing:

(*a*) the ground levels,

(*b*) the invert levels of drains or sewers,

(*c*) the levels of top and bottom of the Municipal manhole,

(*d*) the level of sewers at the manhole referred to under (*c*) above,

(*e*) gradients and sizes of sewers.

(iv) Detailed drawings of particular parts whereever required.

Report And Plans For Water-supply Proposals.

(i) A report clearly describing the proposed works stating also how the existing methods, if any, are defective. It is recommended that the report should be a self-contained one avoiding reference to other papers and correspondence between various offices. The report should also contain the quantity of water that will be drawn off the Municipal main.

(ii) A plan showing:

(*a*) the alignments of proposed service pipes with their sizes marked in inches;

(*b*) the position of Municipal main from which the connection is taken off and its size;

(*c*) positions of valves, meter, etc.;

(*d*) pressure or head of water in the Municipal main as taken at the fountain nearest to the point of offtake and at any time between the hours of 6 to 9 A.M. or 3 to 6 P.M. should be marked on the plan. The pressure to be taken from a pressure gauge which may be attached to a tap by means of a short length of rubber tube.

Estimates.

The usual detailed and abstract estimates, so that the various fittings and connections may be observed, should also accompany all proposals.

Drainage And Sanitary Fittings.

1. Pipe sewers should as a rule be adopted to deal with sullage, open drains being constructed to carry off storm water only.

2. The following table gives the minimum grades (to produce self-cleansing velocity) and the discharging capacities at those grades of a few sizes of open semi-oval drains and pipe sewers. Wherever possible the drains and sewers should not be laid flatter than at these grades. In cases where the minimum grade is not available, automatic flushing tanks should be put in *at the head* of such sewers. Automatic flush tanks should also be put in at the head of *all* long lengths of sewers.

Semi-oval open drains.				Pipe sewers.		
Size in inches.	Grade 1 in	Discharging capacity, gallons per minute.	Area that can be drained in square feet allowing ½" rainfall per hour.	Size in inches.	Grade 1 in	Discharging capacity, gallons per minute.
6	100	166	38,484	4	52	82
9	200	363	83,808	6	100	185
12	300	656	151,542	9	190	415
15	400	1,052	242,870	12	295	739
18	500	1,551	358,126	...	...	...
21	650	2,071	478,138	...	...	...
24	800	2,685	619,747	...	...	...

N.—A 6-inch drain should not be used for a greater length than 300 feet commencing from the head of any branch.

3. Sewers should, as far as possible, be laid in straight lines, a manhole or inspection chamber being put in at distances not exceeding 300 feet. A manhole or inspection chamber should be put in also at every change of direction in the line of sewer and at all points where a branch sewer or sewers join a main sewer. In selecting the line which a branch sewer should take, the principle of draining to the lowest levels should be observed, that is, the selected manhole on the municipal street sewer to which the branch sewer should be connected should be the lowest and not the highest manhole adjoining the premises to be drained.

4. The sewers should be laid at a minimum depth of 3½ feet except in unavoidable circumstances, in which case they may be laid at a shallower depth, provided there is no heavy traffic passing over the place.

5. Where a branch sewer joins a main sewer at a manhole the channel of the former should be curved so that the direction of flow of sewage in it at the junction may be in line with that in the main sewer, *vide* sketches in plate 203.

6. The branch sewers should join the main sewer at its top level, *i.e.*, the R.L's of the tops of the main and branch sewers should be the same. They should *not* join either above or below this level.

7. If the existing municipal sewer is at a great depth to admit of the junction being carried out without going to the expense of making heavy excavations for the branch sewer, a drop arrangement may be provided as shown in sketch in plate 203.

8. To prevent the passage of sewer air into the buildings, traps (disconnecting syphons having a water seal of at least 2 inches) should be provided between the branch sewer and the building in cases where the connection is not from a water closet. In the latter case the water closet itself contains a water seal, and there should be no disconnecting trap inserted between the water closet and the branch sewer. A disconnecting trap (which may be placed in the last manhole or inspection chamber within the boundary of the premises) should always be provided before connecting the branch sewer with the municipal sewer. An air inlet should be provided at the disconnecting trap manhole.

9. Ventilation pipes should be provided at the head of all branch sewers, and these pipes should be carried up to 4 feet above the eave of the roof within 20 feet radius and should be provided with wire domes at their tops.

10. The cast iron soil pipes from water closets and downtake pipes from sinks, etc., should be placed against the *external* face of the wall of the building, and these pipes should also be carried up to 4 feet above the eave of any roof within a radius of 20 feet and be provided with wire domes at their tops.

11. When the building contains more than one floor and water closets are provided on each floor, anti-syphonage pipes should be provided to prevent the taps on the lower floors becoming unsealed by the down rush of water through the soil and downtake pipes from the upper floors. These pipes should also be carried up to the same height as the soil and downtake pipes and be provided with wire domes in a similar way.

Water Service Connections.

1. The service pipes should be from 1¼ inches to ¾ inch and best ½ inch screw down cocks tested to about 200 lbs. pressure should be used.

2. A meter in a suitable masonry pit should be provided on the service pipe just inside the compound of the building.

3. No service pipe should be connected direct on to a latrine, water closet or a flushing tank above it. It should discharge into an independent storage tank at top from which connections may be made.

APPENDIX E.

SIMPLE INSTRUCTIONS FOR BORING AS CIRCULATED TO LOCAL BODIES IN THE PRESIDENCY OF MADRAS BY THE GOVERNMENT OF MADRAS.

General.

The following instructions describe the method of making borings of about fifty feet deep to test the nature of soil and quality of water at a proposed site for drinking water well.

List Of Tools And Plant And Materials Required.

2. A list of tools and plant required for such borings is printed below giving also the object of each of them. Plate 187 gives a sketch of each of the tools and the item numbers correspond to the numbers marked against each :

Item No.	Quantity required.	Tool or plant.	Object.
1	No. 1	Open (clay) auger, 2½'' size	To bore through and bring up clay or other stiff soil.
2	" 1	Worm do. do.	To loosen stuff too stiff for clay auger.
3	" 3	Nose shell do. do.	To bore through and bring up loose stuff.
4	" 1	Flat chisel, 2¾" size	To loosen and pound hard stuff.
5	" 1	V do. do.	do harder stuff.
6	" 4	Hand dogs, 1" size	For raising and lowering rods and tools and holding them on the borehole when making or unmaking the joints between them. Hand dogs also to fasten and unfasten the joints between rods and tools.
7	" 1	Lifting dog do.	
8	1 set	Tiller rods, with screws complete	To serve as a lever in working the tools.
9	No. 1	Swivel rod (short), 1" size	To form the topmost one of lengthening bars allowing rope attachment and turning of rods when working.
10	" 4	Lengthening rods, 10' long each and 1" square ...	To make rigid connection between the boring tool at bottom of borehole and the topmost rod.
11	" 1	Lengthening rods, 5' long each and 1" square	
12	54 L feet.	Boring pipes, 3" internal diameter and ½" thick; screw joints, flush inside and outside ...	To line the borehole to prevent its sides collapsing.
13	2 sets.	Pipe clamps or rests (long type) ...	Various uses described in the notes.
14	No. 1	Bell screw or bell box	To recover rods or tools accidentally remaining in the borehole.
15	" 1	Crows foot.	
16	" 2	Four-ton lifting bottle jacks with wrought iron cylinder	To raise lining pipes or augers which have stuck fast.
17	" 1	Iron pulley...	For tripod at top.
18*	" 1	Wooden platform	For men to stand on and work.
19	" 3	Casuarina or similar poles, 25' to 30' long ...	For making a tripod or derrick.
20	" 2	Manilla rope coils, 50' long and 3" in circumference	For jumping tools, etc.
21	" 1	Monkey spanner, 12" size	For tightening nuts, etc.
22	" 1	Do. do. 10" do.	
23	" 1	Mammooti	
24	" 2	Crow bars, 5' long	
25	" 1	Cutting knife (billhook)	
26	" 1	Clay auger cleaner	To take out contents of clay auger.
27	" 1	Nose shell do.	Do. of shell auger.
28	" 1	Measuring tape, 50'	

* Can be made locally by joining two main pieces of good planks at right angles to each other with a hole in the centre and nailing thinner cross planks over these in each of the four quadrants as illustrated in the figure.

In addition to these about five viss of spare coir rope and about one viss of castor oil should always accompany the tools when taking them out to the field for actual work so that there may be no suspension in the work with the consequent loss of time and money for want of these sundry materials; also a pair of sleepers or similar material each nine to ten feet long to put across the top of the pit which is often necessary during work.

Preliminary Pit.

3. In commencing to bore at any given spot the first thing to be done, in all cases where it is possible, is to sink a pit of square dimensions 7' ×7' to a depth of about eight feet and commence boring from its bottom. This pit will facilitate work and saves delay in the progress of boring. In any case the bottom of the pit should be kept six to nine inches above the subsoil water level when the same is within ten feet of the ground surface.

Soils Classified.

4. The most usual kinds of soil to be bored through are:

(i) Soils of various degrees of stiffness, *e.g.* clay, loam, kankar, etc.

(ii) Loose soils, *e.g.*, sand, gravel, pebbles, silt, etc.

(iii) Hard soils, *e.g.*, different kinds of rock.

Boring Through Stiff Soils (Class I).

5. The stiff soil auger is taken, its screw threads oiled and the swivel rod screwed on to it. A tiller set is then fastened on to the swivel rod to form a lever, and the auger with the attachments is held upright in a small hole made by jumping a crowbar two or three times into the ground or the bottom of the pit. Steadying the whole plant, and holding it quite plumb until it sinks a few feet, a rotatory motion is given to the plant *in the direction of the hands of a clock*, applying a slight downward pressure over the tillers during rotation. The auger sinks into the ground piercing a hole and collecting the soil in the longitudinal slit in the tool. When the auger has sunk to a sufficient depth, the whole thing is lifted up, and the clay collected in the slit taken out. The whole operation is repeated over and over again. When about three feet has been bored through, two men can seat themselves on the tiller rods to give downward pressure for the tool, and additional pressure, if necessary, may be given by attaching two hand dogs to the lengthening rod over the tillers in a direction at right angles to the same and two more men seating themselves on the hand dogs.

6. The borehole need not be lined in this class of soils unless it is necessary to preserve them for some time, say a fortnight or so. The method of lining will be described under soils of class II.

Boring Through Loose Soils (Class II).

7. In this case the borehole will not stand by itself as in the previous case as the soil in the sides of the borehole does not stand vertical. Hence the borehole has to be *lined* which is done by sinking wrought iron tubes as the borehole proceeds.

8. A tripod made of three casuarina or other poles is first raised over the spot of borehole and the pulley, suspended at its top with the manilla rope around the same, and the swivel rod attached to one end of the rope. (The poles forming the tripod should be about 25 to 30 feet long if a convenient height of tripod is to be formed to suit all localities). Having raised the tripod, a lining tube is taken, a clamp attached at a convenient height of its length, and the pipe with the clamp held upright on the spot (if possible stay it by burying a short length, say two feet). Then the swivel rod is screwed on to a nose shell auger and both lowered into the pipe slowly. If the length of the swivel rod be found insufficient, one of the ten feet lengthening rods can be used. When the tool reaches the bottom of the borehole it is worked up and down continuously by the men who hold the other end of the rope. In this operation the sand or loose material gets into the socket of the nose shell auger and fills it as the valve at the bottom of the tool keeps the same from slipping out again. As jumping goes on, the lining pipe sinks down of itself in the first stages of boring thus clearing a hole through the loose soil.

9. When the nose shell auger is filled with sand (generally indicated by the lining tube not sinking further when the tool is worked) it is hauled up, detached from the rods, and the contents emptied. (In emptying the contents, the shell auger is held valve end upwards, a little water poured in from the top and the contents pricked from bottom with the cleaning rod until they run out; in some cases only where the contents stick fast in the auger the tool may be jumped with screw end downwards three or four times on a log of wood when the contents will run out, but this should be avoided as far as possible). The operation is repeated to continue the borehole deeper.

10. In working the nose shell auger the loose soil should be mixed up with water; hence in cases where the subsoil water level is not reached near the bottom of the pit, a quantity of water (an ordinary potful would do) should be added to the borehole so that it may have some water in it when working the auger.

Verticality Of Lining Pipe.

11. The lining pipe should be carefully held up quite plumb until it sinks, say five feet. (A practical and ready method of doing this is to ask two men facing the pipe at distances of ten about to stand

feet from the same and along two lines at right angles to each other; each will then direct the men who hold the pipe to its verticality.)

Sinking The Lining Tubes.

12. The wooden platform is then slided down the pipe, and fixed on the same at a convenient height between two pairs of pipe clamps. Some of the men then get over the platform and work from there. The additional weight now put on the pipes will generally be found sufficient to cause them to sink of themselves till about fifteen feet deep. Beyond this depth, a rotatory motion in clockwise direction should be given to the lining pipe as the nose shell auger is worked, by means of two levers formed by letting in two crowbars at opposite ends into the open spaces between a pair of clamps fixed to the pipe. This rotatory motion does not in practice injure the screw threads of pipes when boring to the shallow depths under consideration. When the pipe has sunk about 35 feet, additional weight has to be put on the platform in the shape of either sand bags or some heavy iron materials lying on the works. As each pipe sinks nearly to the full depth another one is screwed on to its top. In driving the pipes down, only weighting and rotating methods as described above should be used, and *on no account* should blows be given at their tops, even by placing a wooden log, etc., to act as a cushion. Hammering at top will only result in injuring the top of pipes and screw threads, with the result that the succeeding pipes cannot be screwed on to them.

Stick-fasts.

13. There is one important point to be very careful about in working with the nose shell auger, and that is to *avoid "stick-fasts."* The nose shell auger should never be allowed to rest even for a few seconds at the bottom of the bore-hole, else the inrushing sand and grit under the force of subsoil springs, when working in loose sandy strata, jams the tool fast in the pipe. As soon as the tool is filled with sand, or if it be found necessary to stop jumping for a short time when the auger is in the bore-hole, the tool should be hauled up say ten or fifteen feet and there allowed to rest in the bore-hole. If, in spite of precaution, a stick-fast should occur (it invariably does until the workmen themselves experience it once or twice) it is useless to try to extract the tool by merely pulling it up without the aid of jacks: no recourse whatever should be taken to such devices as turning the rods in the hope of loosening the tool and pulling it up, which will only make matters worse. The easiest way to tackle the situation is to raise the lining pipes bodily about 6 inches at a time to about two feet and keep on giving an upward jerk to the tool and rods by means of the rope. The sand or grit jamming the tool then sinks down and in the majority of cases the tool comes up.

14. Where alternative strata of sand and clay have to be bored through, a combination of the two methods described till now should be used. In this case, the lining pipes have to be sunk through the clay also to reach the underlying sand.

Boring Through Hard Soils (Class III).

15. In this case the soil does not yield either to the clay or nose shell auger. It should first be loosened:

(1) by working the worm auger just in the same manner as the clay auger and bringing up the loose material (if it does not come up stuck in the spirals of the tool itself) by working the clay auger.

(2) by jumping the flat or V chisel according to the hardness of the soil and bringing up the loosened or broken materials by using the nose shell auger. At every jump of the chisel it should be slightly turned so that it may not cut through the soil in one and the same place, but break or pound it right round.

The methods described in this paragraph are only for boring in moderately hard soils and not in solid rock such as gneiss or granite which will not be required in the case under consideration.

Care Of Tools And Plant.

16. The above are a few simple instructions on the method of taking ordinary borings and the use of tools involved in the same for the use of beginners in the work, who should, in addition, exercise good care in the preservation of the tools and plant in good condition which is quite essential to the efficient and quick progress of the work as well as to minimise the recurring expenditure on the comparatively costly materials. The screw threads of the tools, rods, pipes, etc., should always be kept oiled and not allowed to rust nor carelessly thrown away on the works. The valves of the nose shell auger get damaged at intervals depending on the extent to which they are used. Of the three tools supplied, one should always be kept as a reserve *on the works* and the other two used alternately. The damaged one should *at once* be repaired. This could be done even in out-of-the-way places if a spare piece of good leather, which is often difficult to obtain even in small municipal towns, be kept on hand with the tools.

Recovering Tools From Boreholes.

17. Now regarding the use of the two tools under items 14 and 15 in the list given at the beginning of these notes, they are of service in extracting the tools and rods that may accidentally drop or remain in the bore-hole. When the screw head is left on,

the bell box is let in and an attempt made to screw on the same to the top end of the rod or tool and the whole hauled up. If the screw end has broken off then the crows foot is let in and the rod or tool caught by the same and the whole hauled up.

Observation And Record Of Results.

18. A vital point in connection with the work described up to now is the careful observation and recording *then and there* of the depths from which the various kinds of soil were obtained. When lining pipes are being sunk in sand strata by working the nose shell auger, the depth from which the soil in the shell auger is obtained is that to which the pipes have sunk; to facilitate these observations being readily made and with no mistake a gauge in feet should be marked with chalk temporarily on each lining pipe as soon as it is screwed on to the one below. The number of feet should be carried up continuously from the lowest pipe of the series. The depth observed should be from ground level for which purpose a string line may be stretched across the top of the pit and the point where it touches the lining pipe read. When using clay auger, chisel and other tools, the observations of the depth at which the tool worked should be made every time and *before the tools are hauled up* for emptying the contents, etc. The water level also should be noted. A very convenient and accurate method of sounding the water level in boreholes is to tie a lead sounder made, shape shown in sketch (figs. 29 and 30, plate 187), to the end of the measuring tape and sound the water level.

The water level should be observed in the morning before the work commences as it is only then that the true rest level of the sub-soil water is obtained. Also the level at which the water was tapped in a bore-hole should be noted in all cases.

Plotting Of The Results.

19. From the field records made, a section should be plotted *to scale* showing the strata of the soil lying at different depths below ground level and water levels as shown in the sketch (fig. 38, plate 187).

Pulling Out The Lining Pipes.

20. When a boring has been finished and the required results obtained, it will be necessary, in the cases under consideration to pull the lining pipes out. This could be done by fastening a pair of clamps on the pipe and applying levers on both sides with the crow bars. If the pipes have stuck too fast for this, the screw jacks should be used.

APPENDIX F.

EXTRACTS FROM THE WATER WORKS HANDBOOK BY J. C. MOLONY, Esq., I.C.S., PRESIDENT, CORPORATION OF MADRAS.

Introduction.

This book is too long to re-print in full. These extracts give the salient points. Those who want further information can obtain a copy of the Handbook from the Corporation of Madras. Price 2 annas.

Time Of Reading Meters.

The meters will be read as far as possible on identical dates every month and within the first ten days of the month. The Meter Reader or Overseer will give at least 24 hours' notice ahead of date of reading the meter. As it is impossible to fix the exact time, a margin of three hours within which the meter will be read, will be noted on the notices.

The Meter Reader or Overseer has instruction to send word through the gardener or other servant to the owner or occupier, if the latter is not directly accessible, as soon as he reaches such owner or occupier's premises, and to wait for 5 minutes only for such owner or occupier or his representative to witness the reading. In the absence of any of the abovementioned persons the Meter Reader or Overseer will read the meter, note the reading, and hand over a copy to gardener or servant of any of the abovementioned persons.

Method Of Reading Meters.

The meter dials are of two types:

(1) Straight reading dials.

(2) Circular reading dials.

Straight reading dials are of the speedometer type and no instructions are necessary for reading meters with this type of dials.

Circular reading dials: There are about six types in use. The instructions will be found at the end of this appendix.

Meters Recording Incorrectly.

In the case of meters found to be recording incorrectly, the President will, until the meter is repaired and replaced, base his assessment of the quantity consumed on the average consumption of the six months previous to the month in which the meter was considered to have gone out of order.

House Service Connection.

A house service connection shall ordinarily comprise the following parts and fittings:

(*a*) A brass or gun metal ferrule inserted in the street main.

(*b*) A lead or properly protected iron or steel communication pipe from the ferrule to the stopcock.

(*c*) A stopcock and its surface box.

(*d*) A meter and its pit.

(*e*) Service pipes from the stopcock to the taps.

(*f*) Taps and other fittings.

Meters.

The President may at his discretion fix a meter to any service pipe, whenever and for such length of time as he may consider necessary. The cost of fixing and removing such meter shall be paid by the owner or occupier who shall also pay to the Corporation rent for the meter at such rates as from time to time may be fixed by the Corporation.

Connection To The Main.

No connection with any Municipal water work shall be made, renewed, altered, or extended:

(*a*) except by a Municipal officer or servant empowered in that behalf by the President, and

(*b*) until the certificate as required by the rules has been given.

Specification Of Pipes And Fittings.

All consumer's pipes shall be of lead, wrought iron, cast iron, steel, brass or copper, as may be required by the President and shall conform in every respect to the following specifications:

Where a connection is made between an iron and copper pipe or lead pipe, a screw ferrule of hard brass shall be wiped on to the lead pipe.

Joints in lead pipes shall be water tight plumbers or wiped solder joints. No other form of joint, such as copper bit or flange joints shall be employed except with the Engineer's permission in writing.

Bends in pipes shall not in any case diminish or alter the bore of the pipes.

Stop taps shall be provided on all primary branches from the supply pipes in buildings with more than one tenancy.

Every pipe or fitting within a building shall so far as practicable be so placed as to be readily accessible for examination and repair, and no pipe shall be embedded in brick, stone, mortar, plaster or similar materials, except where this is unavoidable.

All services shall be so laid as to render impossible any contamination from drains or latrines, and if necessary, they shall be laid at higher level than the house drain.

Lead Pipes.

Lead pipes shall be of equal thickness throughout, and of the following weights per lineal yard.

Internal diameter of pipe in inches.	Weight of pipes in lbs. per lineal yard.
$\frac{3}{8}$	4 lbs.
$\frac{1}{2}$	5 "
$\frac{3}{4}$	8 "
1	11 "
$1\frac{1}{4}$	14 "
$1\frac{1}{2}$	18 "
2	34 "

Cast Iron Pipes.

Cast iron pipes, if used in connection with water supply, shall comply with the specification issued by the Engineer from time to time.

W. I. and Steel Pipes.

Wrought iron and steel tubes, if used in connection with water supply shall conform to the dimensions given in the following table and otherwise shall comply with the Standard Specification for pipe Threads (Publication No. 21) issued by the Engineering Standard Committee.

Nominal bore of tube in inches.	Approximate outside diameter of tube in inches.	Number of threads per inch.
$\frac{1}{2}$	27/32	14
$\frac{3}{4}$	1 1/16	14
1	1 11/32	11
$1\frac{1}{4}$	1 11/16	11
$1\frac{1}{2}$	1 29/32	11
2	2 3/8	11

The screws in all tubes shall be conical, having a taper of $\frac{1}{16}$ inch on the diameter per inch of length, and in all cases shall be screwed with the British Standard Pipe Threads for Iron or Steel Tubes.

Protection Of Iron And Steel Pipes.

Wrought iron, cast iron and steel pipes must be protected on the inside from corrosion, either by galvanising or coating with a suitable material satisfactory to the Engineer.

Wrought iron and steel pipes or tubes whether galvanised or not shall not be laid in earth unless coated and protected by one of the following methods:

(*a*) The pipes shall be tightly wrapped with stout tape of approved quality, samples of which may be seen at the Corporation Stores. Before applying, the tape must be dipped in and thoroughly coated with petroleum pitch or Siderosthen paint or other approved coating: After wrapping, the interstices of the material shall be filled up with a final coating of the preservatives which may be painted on with a brush. The coating to be applied to the pipe shall be the same as for the tape.

(*b*) The pipes shall be laid in a trough made of teak wood and filled with pitch. Cradles must be fixed in the trough not exceeding 6 feet apart in order that the pitch may entirely surround the pipe, and to prevent the pipe from rising or sinking through the pitch, the minimum thickness of pitch at any point round the pipe being five-eighths of an inch.

When long lengths of piping are required, the protection must be applied previous to laying. Overseers and plumbers who desire to keep a stock of house service pipes must have the pipes properly treated before use.

If, however, only a short connection is required, for which short pieces of piping or specials alone can be used, the protective coating may be applied in the trench when the pipes have been jointed up.

Under no circumstances must any gaps be left in the protective covering of house service pipes laid in earth. No pipes must be covered up until the protective coating has been inspected and approved by the Engineer.

Note: Lead pipes in earth need not be protected according to the above rules.

Brass And Copper Pipes.

All brass and copper tubes used in connection with water supply shall be solid drawn and of a minimum thickness of 14 Imperial gauge, and shall be screwed with the British Standard Pipe Threads for Iron and Steel Tubes.

Taps, Etc.

Ordinary taps must be of the screw-down or non-concussive type. Ordinary taps of the plug or quick closing type will not be allowed. Waste-not taps must be of a type approved by the Engineer.

Every tap or cock on a supply pipe shall be made full bore, well-dressed and free from sand, capable of resisting a pressure of at least 300 lbs. to the sq. inch

Every tap or cock shall be made of gunmetal or hard brass, or of other not less suitable metal or alloy and shall be of sufficient strength and weight in every part. Every bib tap or stopcock shall have an efficient screw-down valve. Every stopcock shall be fitted with a square head. The valve of a screw-down bib tap and the valve of a screw-down stopcock, if intended to be used for cold water, shall be faced with specially prepared leather or other suitable material and if intended to be used for hot water shall be faced with a material adopted for use for hot water. Such valve if faced with a soft washer, shall be so constructed as not to be liable to turn round on its seat, and if faced with vulcanite or other hard material, shall be so constructed as to turn on its seat before tightly closing.

Premises Not To Be Supplied Through More Than One Supply Pipe.

No dwelling house or other premises charged or chargeable separately with water-rate or rent shall be supplied with the water of the Corporation by more than one supply pipe connected to the Corporation main except with the consent in writing of the President of the Corporation.

Separate Supply Pipe To Every Dwelling House.

No communication pipe shall be used to supply water to more than one dwelling house or other premises charged or chargeable with water tax or rate, except with the consent in writing of the President of the Corporation. In the event of any such consent being granted, the supply shall remain subject to the provisions of the Municipal Act.

Position Of Stopcock.

An approved screw-down stopcock provided by the Corporation at the cost of the consumer, shall be placed in such an accessible position as may be approved by the authorised officer, and if underground, shall be protected by a proper guard box (or surface box) of approved design.

Taps For Drinking Water.

In all cases where a constant supply of water is provided by the Corporation, taps available for drawing water for drinking or cooking purposes shall, as far as possible, be supplied from the service pipe, and not from any cistern.

Consumer's Outside Taps Or Stand Pipes.

No consumer's tap or stand pipe shall be fixed in any public thoroughfare, common staircase, passage, or outside any premises without special permission in writing from the President of the Corporation. Every stand pipe or fountain, which is accessible to the occupants of more than one dwelling house, shall be provided with a self-closing or other suitable waste preventing tap. No such tap or stand pipe shall be used for drawing water unless and until it has been approved by the authorised officer. If in the judgment of the authorised officer, any such tap or stand pipe shall, either directly or indirectly conduce to or be used or dealt with as to cause contamination, waste or misuse of the water of the Corporation, such tap or stand pipe shall be removed by the consumer within fourteen days of the receipt by him of a requisition to that effect signed by the authorised officer.

Pumps Drawing Water Direct From Water Supply Pipe.

Pumps drawing water direct from the water supply pipe are objectionable, and will only be allowed by special permission of the President for a limited period which may, however, be extended from time to time by the President. Such pumps shall be open to inspection at any time, and should the President consider it necessary, will have to be removed at 24 hours' notice, and no claim shall lie against the Corporation for damages for removal of such a pump.

Meter And Meters Rents.

The President may fix meters on house services irrespective of the class of service.

In the case of metered services, the following rents for meters will be charged :

		Rs.	A.	P.	
½ in.	...	... 1	0	0	per mensem.
¾ in.	...	... 1	4	0	"
1 in.	...	... 1	8	0	"
1¼" to 1½"	...	... 2	0	0	"
2 in.	...	.. 2	8	0	"
3 in.	...	... 3	0	0	"
4 in.	...	... 4	0	0	"
5 in. and above		... 5	0	0	"

Free Allowance.

For domestic purposes, a free monthly allowance is granted equal to 160 gallons per Rupee of the monthly rental value as assessed by the Revenue Officer. All excess will be charged for at as, 12 per 1,000 gallons.

Siemens And Adamson's Water Meter: Instructions For Reading The Dial: Registering In Gallons: Fig. 1, Plate 192.

In all meters, up to 6 inch, each revolution of the hand corresponds to a flow of 1,000 gallons.

In the dial of this meter are two large circles and one small inner circle. The outer large circle referred to by the fixed pointer, represents 1,000 gallons each revolution; it is divided into 100 equal

parts of 10 gallons each. The inner large circle, referred to by the movable hand, represents 100,000 gallons each revolution ; it is divided into 100 equal parts of 1,000 gallons each. The small inner circle represents 1,000,000 gallons each revolution, and is divided into 10 parts of 100,000 gallons each.

In this figure the hand in the small circle has last passed 6, indicating six revolutions of the large hand, or 600,000 gallons ; the large hand indicates 22,000 and the fixed pointer 250 gallons, so that the meter reading is 622,250 gallons.

Siemens And Adamson's Water Meter: Instructions For Reading The Dial: Registering In Gallons: Fig. 2, Plate 192.

In all meters up to 6 inch each revolution of the hand corresponds to a flow of 1,000 gallons. In the dial of this meter are two large circles and two small inner circles. The outer large circle, referred to by the fixed pointer, represents 1,000 gallons for each revolution; it is divided into 100 equal parts of 10 gallons each. The large inner circle, referred to by the movable hand, represents 100,000 gallons for each revolution; it is divided into 100 equal parts of 1,000 gallons each. The small inner circle on the right side represents 1,000,000 gallons for each revolution; it is divided into 10 parts of 100,000 gallons each. The small inner circle on the left side represents 10,000,000 gallons for each revolution; it is divided into 10 equal parts of 1,000,000 gallons.

This figure has four circles of figures. The circle of greatest value is the small circle marked "ten millions," and on the figure the hand has last passed 2, indicating two millions. The next circle in value is the second small circle marked "one million," and in the figure the hand has last passed 5 indicating 500,000 gallons. The next is the large inner circle, and the division or figure the hand is pointing to indicate 83,000 and the fixed pointer 250 gallons, so that the meter reading is 2,583,250 gallons.

J. Tylor And Son Patent Rotary Water Meter: Instructions For Reading The Dial: Registering In Gallons: Fig. 3, Plate 192.

In the dial of this meter are two large circles and one small inner circle. The outer large circle referred to by the fixed pointer, represents 10,000 gallons for each revolution; it is divided into 100 equal parts of 100 gallons each; the inner large circle, referred to by the movable hand, represents 1,000,000 gallons for each revolution; it is divided into 100 equal parts of 10,000 gallons each. The small inner circle represents 10,000,000 gallons for each revolution ; it is divided into 10 parts of 1,000,000 gallons each.

In this figure the hand in the small circle has not arrived at 1, so that the inner large circle of figures only is taken. In this figure the hand is pointing to 25, and reads 250,000 gallons, the fixed pointer indicates 2,500, so that the meter reading is 252,500 gallons.

J. Tylor And Son Patent Rotary Water Meter: Instructions For Reading The Dial: Registering In Gallons: Fig 4, Plate 193.

The dial of this meter has five hands or pointers. The five hands register respectively 10, 100, 1,000, 10,000, 100,000. In order to estimate the quantity of water which has passed through the meter, it is only necessary to add together the quantity registered by the various hands of the dial, care being taken only to count the completed divisions.

In the above figure the meter reading is 1,32,490 gallons.

J. Tylor And Son Patent Rotary Water Meter: Instructions For Reading The Dial Registering In Gallons: Fig. 5, Plate 193.

The dial of this meter has five hands or pointers. The five hands register respectively 100, 1,000, 10,000, 100,000 1,000,000. In order to estimate quantity of water which has passed through the meter, it is only necessary to add together the quantity registered by the various hands of the dial, care being taken only to count the completed divisions.

In this figure the meter reading is 3,562,250 gallons.

J. Tylor And Son Patent Rotary Water Meter: Instructions For Reading The Dial: Registering In Gallons: Fig. 6, Plate 193.

The dial of this meter has five hands or pointers. The five hands register respectively 20,1,000, 10,000, 100,000, 1,000,000. In order to estimate quantity of water which has passed through the meter, it is only necessary to add together the quantity registered by the various hands of the dial, care being taken only to count the completed divisions.

In this figure the meter reading is 2,741,160 gallons.

APPENDIX G.

List Of The Madras Sanitary Board Type Designs Which Were In Force On 1st June 1916 With Corresponding Plate Numbers.

Type design number.	Description.	Number and date of the proceedings with which the type design was issued.	Plate numbers.
40	Market, mufassal: 3 sheets	No. 514/S., dated 13th July 1897.	114 to 119
70	Weekly market shed for mufassal stations ...	No. 579/S., dated 6th Oct. 1898.	121 and 122
71	Do. do. ...		120
72	Do. do. ...		123 and 124
89	Compound walls in different materials ...	No. 145/S., dated 1st May 1901.	97 and 98
101	House latrine of one seat	No. 150/S., dated 30th April 1907.	21
102	Removable drain coverings unsuited for wheeled traffic.	No. 151/S., dated 30th April 1907.	210
103	Filter trench for a house	No. 251/S., dated 15th Aug. 1907.	206
104	Removable drain coverings suitable for wheeled traffic.	No. 113/S, dated 5th March 1909.	211
105	Flush latrine with three seats	No. 145/S., dated 20th March 1909.	29
107	Urinals	No. 125/S., dated 22nd June 1910.	35 and 36
109	Cheap dwelling house	No. 24/S., dated 26th Jan. 1911.	9
110	Bacterial filters (with catch pits): 2 sheets ...	No. 96/S., dated 9th March 1911.	207
111	Municipal workshop	No. 112/S., dated 24th March 1911.	178
112B	Latrine of 18 seats	No. 338/S., dated 29th Sep. 1911.	17 and 18
113A	Filter well for the disposal of spill water at fountains.	No. 374/S., dated 19th Oct. 1911.	179
113B	Filter trench for the disposal of spill water at fountains.		180
114	Simple sanitary improvements for conserving village tank water supplies.	No. 281/S., dated 4th May 1912.	162
115	Administrative block	No. 245/S., dated 19th March 1914.	39 and 40
116	Main ward of 40 beds (Medical)	No. 686/S., dated 10th Dec. 1912.	43
117	Do. do. (Surgical)		45
118	Special ward for Indians		47 and 48
119	Do. for Europeans		49 and 50
120	Do. for a larger hospital... ...		51 and 52
121	Maternity ward		53 and 54
122	Isolation ward	Do.	89 and 90
123	Operation theatre	No. 686/S., dated 10th Dec. 1912 and No. 770/S., dated 21st August 1914.	59 and 60

Type design number.	Description.	Number and date of the proceedings with which the type design was issued.	Plate numbers.
124	Door in operation theatre	No. 686/S., dated 10th Dec. 1912.	61
125	Bath room		86
126	General store rooms		76
127	Kitchen		77 and 78
128	Door in kitchen		79 and 80
131	Quarters for hospital servants (6 compartments).		81 and 82
132	Mortuary...		87
133	Site plan for a general hospital		62
134	Main ward of 12 beds	No. 487/S., dated 3rd Sep. 1912.	46
135	Scour pipe	No. 528/S., dated 23rd Sep. 1912, and 270/S., dated 23rd Apl. 1913.	183
137	Well fitted with semi-rotary hand pump ...	No. 554/S., dated 7th Oct. 1912.	153
138	Do. with pump and iron tank with taps.		154
139	Do. do. elevated masonry reservoir and distribution pipes, etc.		155
140	Out-patient dispensary for women and children.	No. 1/S., dated 2nd January 1913.	63 and 64
141	Sub-assistant surgeon's quarters ...	No. 41/S., dated 16th January 1913.	83 and 84
142	Phthisis ward for 12 beds	No. 243/S., dated 9th April 1913.	55
143	Details of shutters in phthisis ward ...		56
144	Open well with 1″ semi-rotary pumps ...	No. 413/S., dated 26th June 1913.	156
145	Deep well with pump, and iron tank with taps or masonry reservoir with taps ...		157
146	Quarters for a civil apothecary or assistant surgeon.	No. 490/S., dated 6th August 1913.	85
147	An epidemic disease shed	No. 599/S., dated 20th September 1913.	91 and 92
148A	Latrine for an out-patient dispensary ...	No. 918/S., dated 19th December 1913.	22
148B	Kitchen and store room for dispensary ...		66
149	Cheap open corrugated iron latrine of 6 seats ...	No. 55/S., dated 24th January 1914.	19 and 20
150	Air valve pit	No. 142/S., dated 19th February 1914.	181
151	Deep well (when the maximum water level is very low) fitted with pumps and tank.	No. 162/S., dated 26th February 1914.	158
152	House service connection with $\frac{3}{4}''$ water meter.	No. 174/S., dated 4th March 1914.	182
154	Col. Smyth's Indian commode	No. 269/S., dated 24th March 1914.	34
155	Slaughter house intended for bullock or sheep...	No. 373/S., dated 22nd April 1914.	37 and 38
156	Conservancy depot. (A model design in 2 sheets).	No. 476/S., dated 19th May 1914.	129 to 135
157	Vaccine station	No. 539/S., dated 12th June 1914.	88

Type design number.	Description.	Number and date of the proceedings with which the type design was issued.	Plate numbers.
158	Out-patient dispensary (large)	No. 609/S., dated 6th July 1914.	67
158-A	Do. do. (front and side elevation and section).		68
158-B	Do. do. (details of lantern and sky light).		69 and 70
	Markets.		
159	Typical site plan	No. 722/S., dated 15th August 1914.	99
159-A	Do.		100
159-B	Do.		101
159-C	Market main entrance		102
159-D	Market entrance		103
159-E	Do.		104
159-F	Do. Details of mullions for upper windows and main arch jamb. ...		105
159-G	Grain and condiment bazaar		106
159-H	Do. do.		107
159-I	Do. do.		108
159-J	Market front corner		109
159-K	Vegetable bazaars		111 and 112
159-L	Mutton and beef stalls		110
159-M	Fish stall		113
160	Open wells	No. 911/S., dated 10th October 1914.	159
161	Deep well fitted with semi-rotary hand pump.	No. 973/S., dated 29th October 1914.	160
162	Out-patient dispensary	No. 1055/S., dated 18th November 1914.	71 and 72
163	Do. with an operation room.	No. 1056/S., dated 18th November 1914.	73 and 74
164	Sewage purification arrangements ...	No. 24/S., dated 9th January 1915.	208
164-A	Do. do.		209
165	Contagious diseases, isolation or cholera ward.	No. 93/S., dated 4th February 1915 and 847/S., dated 12th November 1915.	57 and 58
166	Scavengers' huts	No. 154/S., dated 25th February 1915.	7 and 8
169	Out-patient dispensary (small)	No. 666/S., dated 4th September 1915.	75

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